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(54) OPTICAL TRANSMITTING APPARATUS, METHOD OF INCREASING THE NUMBER OF PATHS OF THE APPARATUS, AND OPTICAL SWITCH MODULE FOR INCREASING THE NUMBER OF PATHS OF THE APPARATUS

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(57) **ABSTRACT**

An optical transmitting apparatus is configured such that K pieces of output ports of optical path switching units whose input port is connected to k-th input transmission path are connected to first to K-th output transmission paths except for the k-th output transmission path and to the k-th input port of a dropping unit, and the optical path switching units and the dropping unit outputs light of wavelength which is part or all of WDM light received from said input port from a specific output port, and can output light having a wavelength different from that of the light output from said specific output port from an output port different from said specific output port. Accordingly, while largely reducing the number of optical fiber patch cords necessary in an optical transmitting apparatus and largely reducing the number of spare ports, the flexible expansion of apparatus function can be realized.

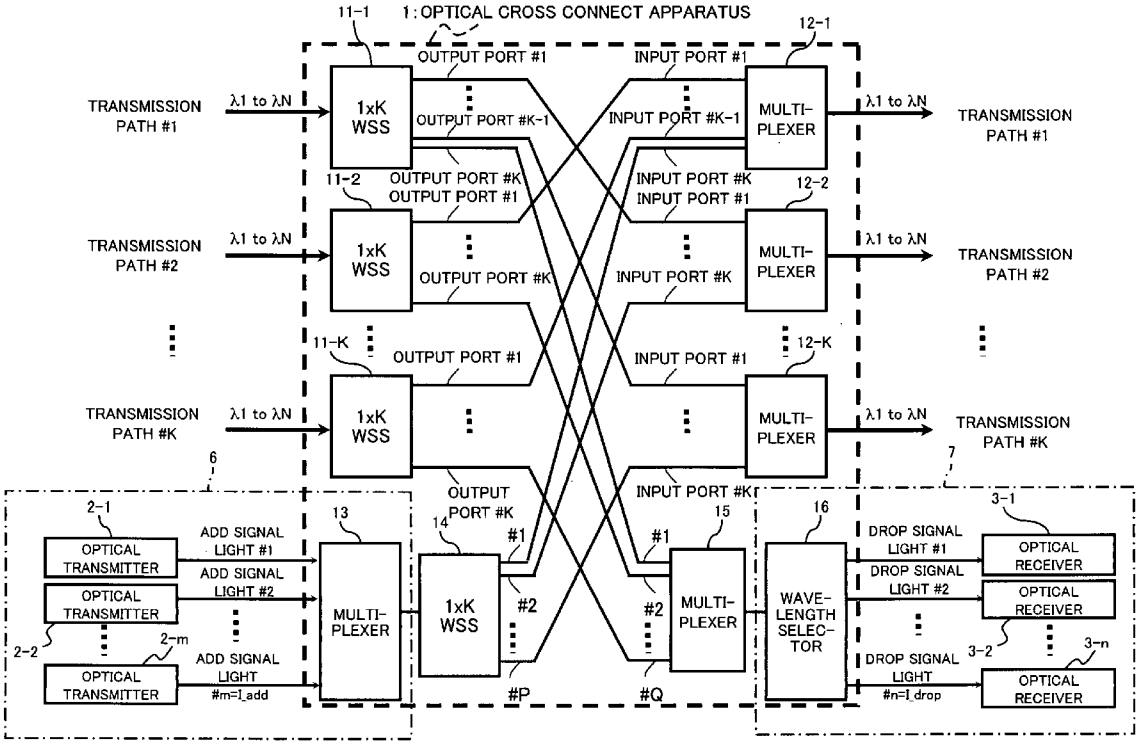
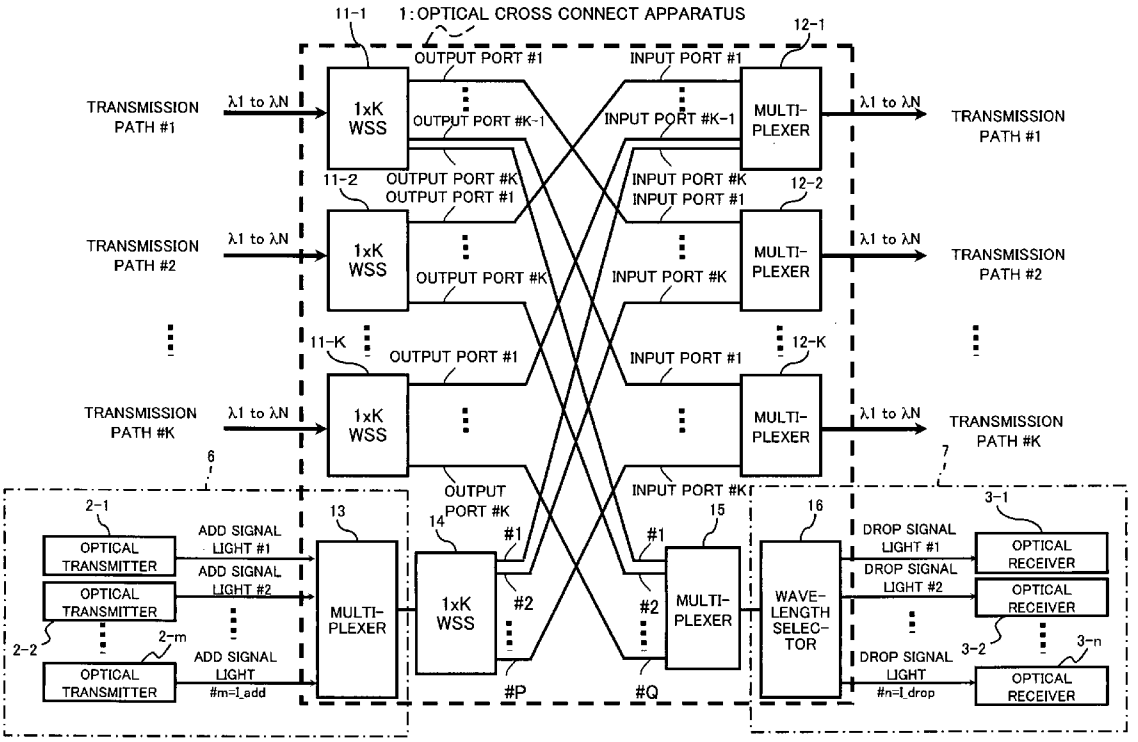


FIG. 1


1:OPTICAL CROSS CONNECT APPARATUS
11-1
11-2
11-K
12-1
12-2
12-K
TRANSMISSION PATH #1
TRANSMISSION PATH #2
TRANSMISSION PATH #K
λ1 to λN
1xK WSS
OUTPUT PORT #1
OUTPUT PORT #K-1
OUTPUT PORT #K
INPUT PORT #1
INPUT PORT #K-1
INPUT PORT #K
MULTI-PLEXER
6
7
2-1
2-2
2-m
OPTICAL TRANSMITTER
ADD SIGNAL LIGHT #1
ADD SIGNAL LIGHT #2
ADD SIGNAL LIGHT #m=I_add
13
14
15
16
#1
#2
#P
#Q
WAVE-LENGTH SELEC-TOR
DROP SIGNAL LIGHT #1
DROP SIGNAL LIGHT #2
DROP SIGNAL LIGHT #n=I_drop
3-1
3-2
3-n
OPTICAL RECEIVER

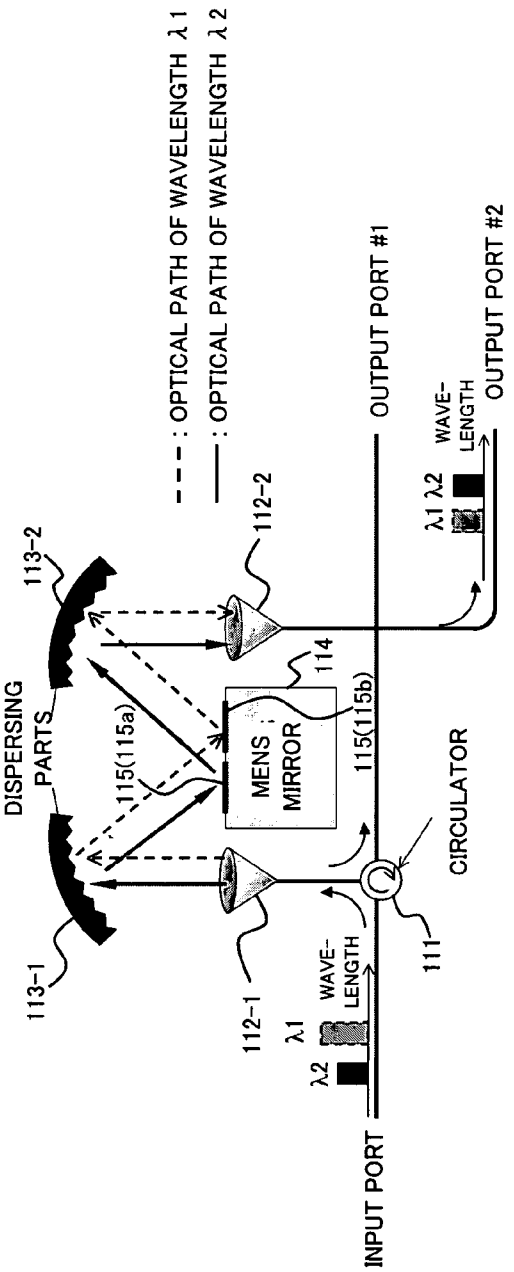

- - - : OPTICAL PATH OF WAVELENGTH λ1
——: OPTICAL PATH OF WAVELENGTH λ2
113-2
112-2
DISPERSING PARTS
115(115a)
MENS MIRROR
114
115(115b)
OUTPUT PORT #1
λ1 λ2
WAVE-LENGTH
OUTPUT PORT #2
CIRCULATOR
113-1
112-1
λ1
λ2
WAVE-LENGTH
111
INPUT PORT

FIG. 2

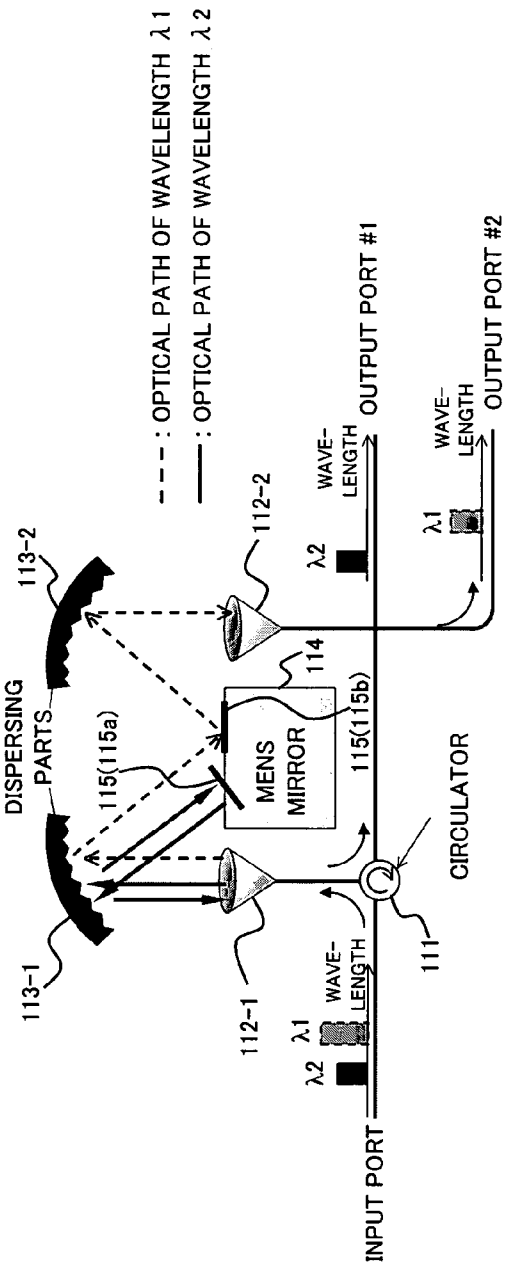

- - - : OPTICAL PATH OF WAVELENGTH λ1
——: OPTICAL PATH OF WAVELENGTH λ2
113-2
112-2
λ2
WAVE-LENGTH
OUTPUT PORT #1
λ1
WAVE-LENGTH
OUTPUT PORT #2
DISPERSING PARTS
115(115a)
MENS MIRROR
114
115(115b)
CIRCULATOR
113-1
112-1
λ1
λ2
WAVE-LENGTH
111
INPUT PORT

FIG. 3

FIG. 4

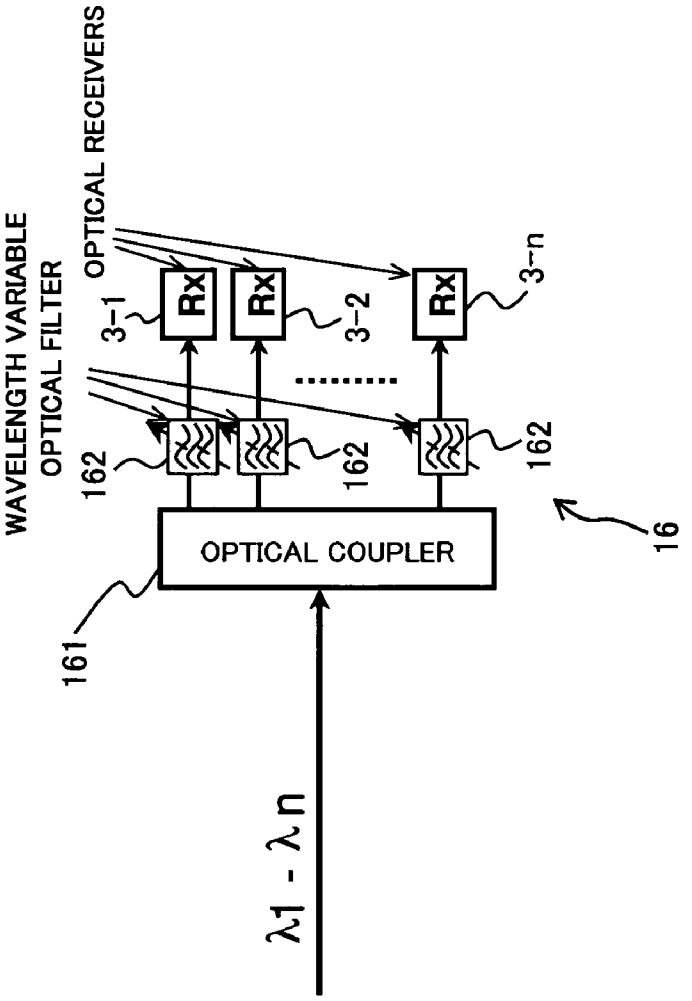

WAVELENGTH VARIABLE OPTICAL FILTER
OPTICAL RECEIVERS
Rx
Rx
Rx
3-1
3-2
3-n
162
162
162
OPTICAL COUPLER
161
16
λ1 - λn

FIG. 5

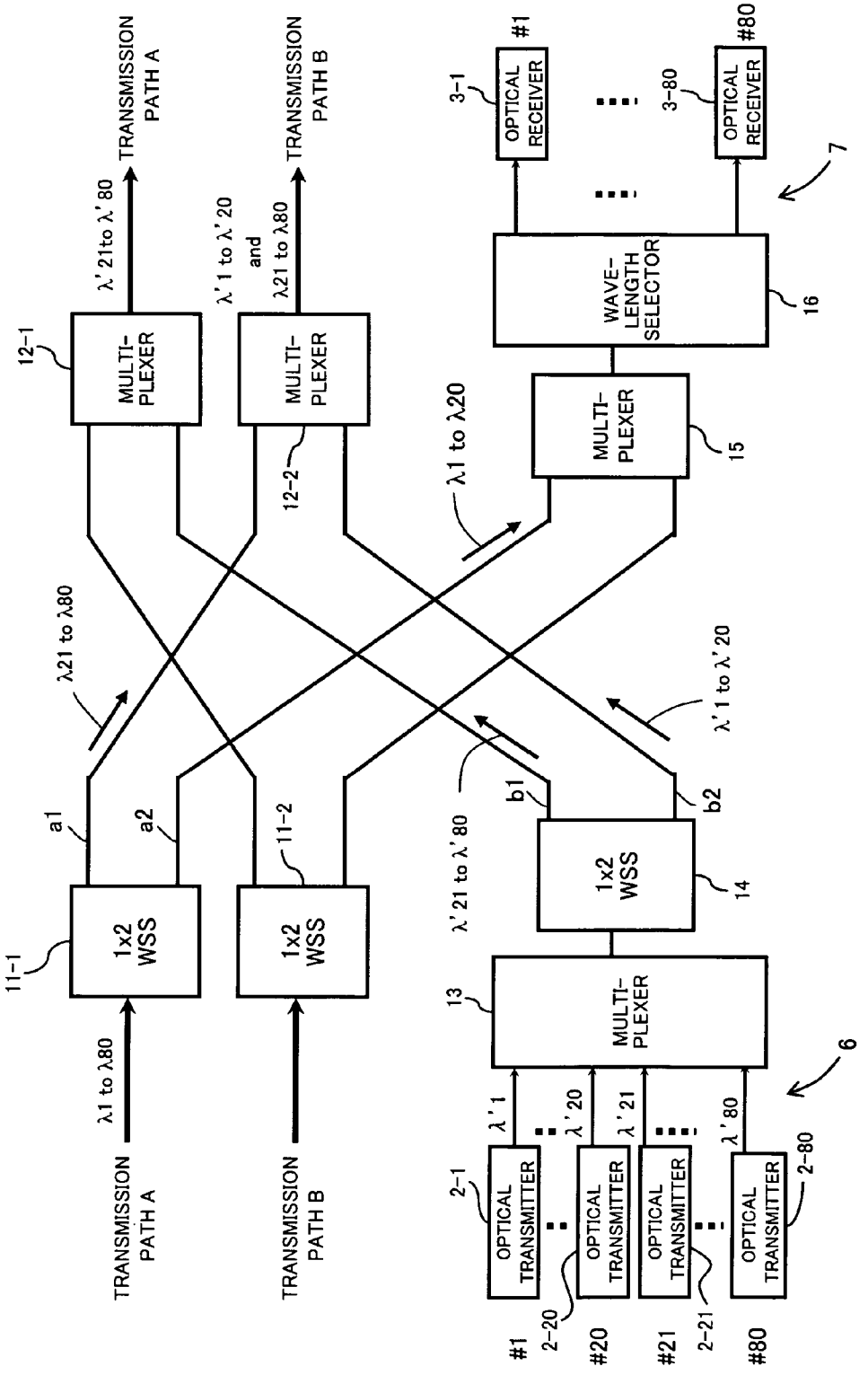

TRANSMISSION PATH A
TRANSMISSION PATH B
λ1 to λ80
11-1
1x2 WSS
a1
a2
11-2
1x2 WSS
λ21 to λ80
12-1
MULTI-PLEXER
λ'21to λ'80
TRANSMISSION PATH A
12-2
MULTI-PLEXER
λ'1 to λ'20 and λ21 to λ80
TRANSMISSION PATH B
λ1 to λ20
MULTI-PLEXER
15
WAVE-LENGTH SELECTOR
16
3-1
OPTICAL RECEIVER
#1
3-80
OPTICAL RECEIVER
#80
7
λ'1 to λ'20
b1
b2
λ'21 to λ'80
1x2 WSS
14
13
MULTI-PLEXER
6
λ'1
λ'20
λ'21
λ'80
2-1
OPTICAL TRANSMITTER
2-20
OPTICAL TRANSMITTER
2-21
OPTICAL TRANSMITTER
2-80
OPTICAL TRANSMITTER
#1
#20
#21
#80

FIG. 6

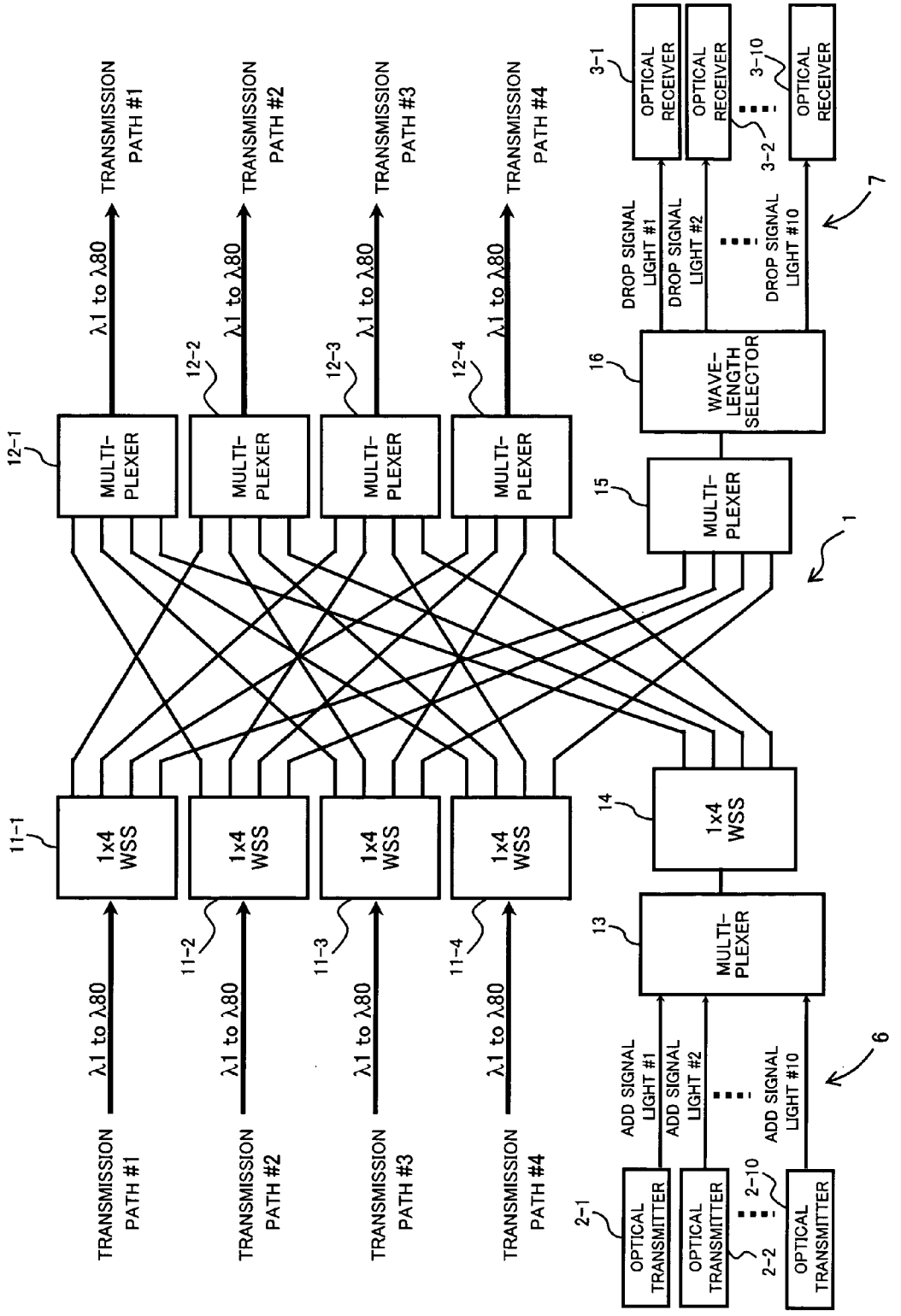

TRANSMISSION PATH #1
TRANSMISSION PATH #2
TRANSMISSION PATH #3
TRANSMISSION PATH #4
λ1 to λ80
11-1
11-2
11-3
11-4
1x4 WSS
12-1
12-2
12-3
12-4
MULTI-PLEXER
15
MULTI-PLEXER
16
WAVE-LENGTH SELECTOR
DROP SIGNAL LIGHT #1
DROP SIGNAL LIGHT #2
DROP SIGNAL LIGHT #10
3-1
3-2
3-10
OPTICAL RECEIVER
7
1
14
1x4 WSS
13
MULTI-PLEXER
ADD SIGNAL LIGHT #1
ADD SIGNAL LIGHT #2
ADD SIGNAL LIGHT #10
6
2-1
2-2
2-10
OPTICAL TRANSMITTER

FIG. 7

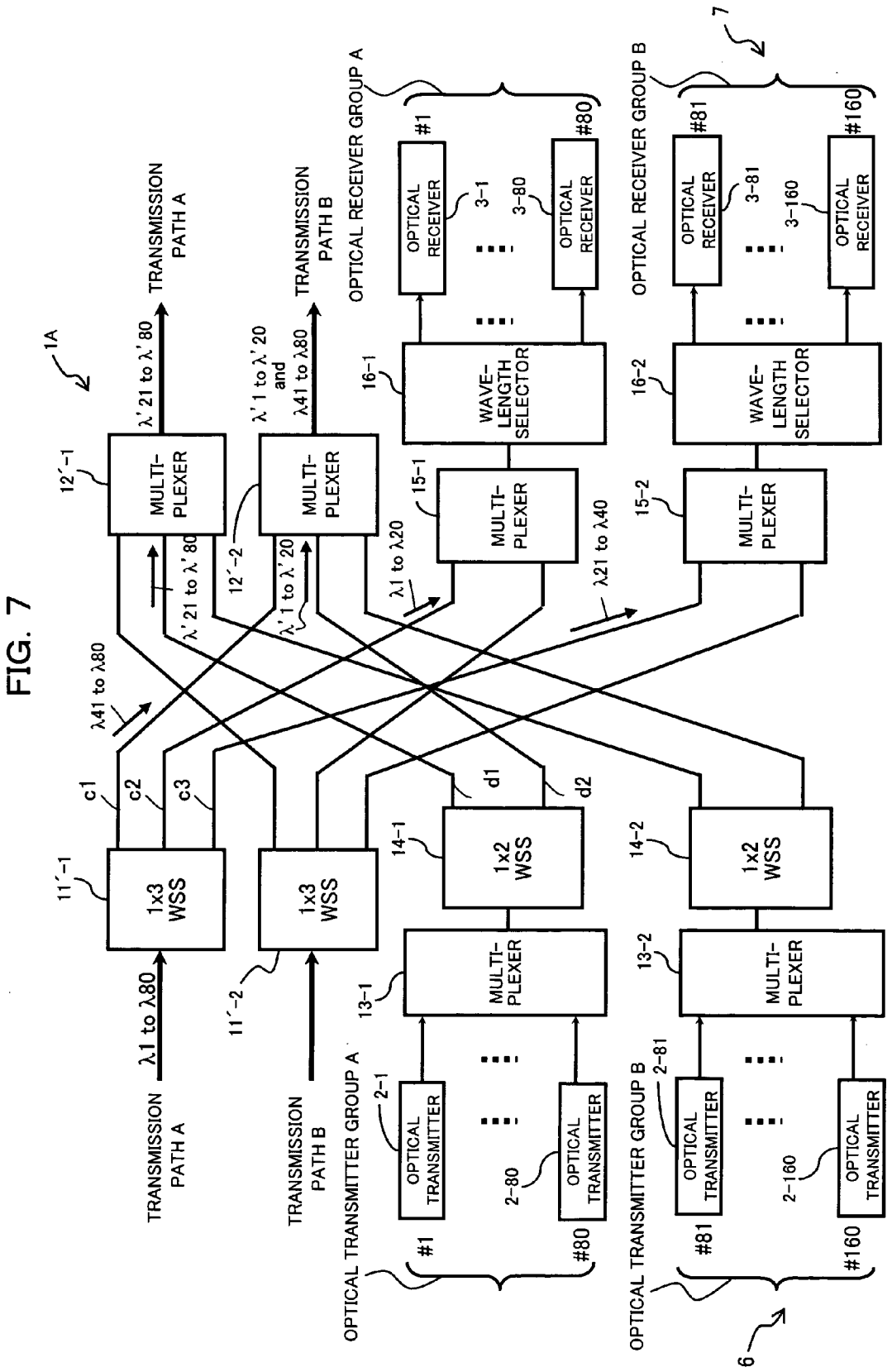

1A
7
6
TRANSMISSION PATH A
TRANSMISSION PATH B
λ1 to λ80
λ41 to λ80
λ'21 to λ'80
λ'1 to λ'20 and λ41 to λ80
λ1 to λ20
λ21 to λ40
11'-1
11'-2
1x3 WSS
12'-1
12'-2
MULTI-PLEXER
13-1
13-2
14-1
14-2
1x2 WSS
15-1
15-2
16-1
16-2
WAVE-LENGTH SELECTOR
c1
c2
c3
d1
d2
OPTICAL TRANSMITTER GROUP A
OPTICAL TRANSMITTER GROUP B
OPTICAL RECEIVER GROUP A
OPTICAL RECEIVER GROUP B
OPTICAL TRANSMITTER
OPTICAL RECEIVER
2-1
2-80
2-81
2-160
3-1
3-80
3-81
3-160
#1
#80
#81
#160

FIG. 8

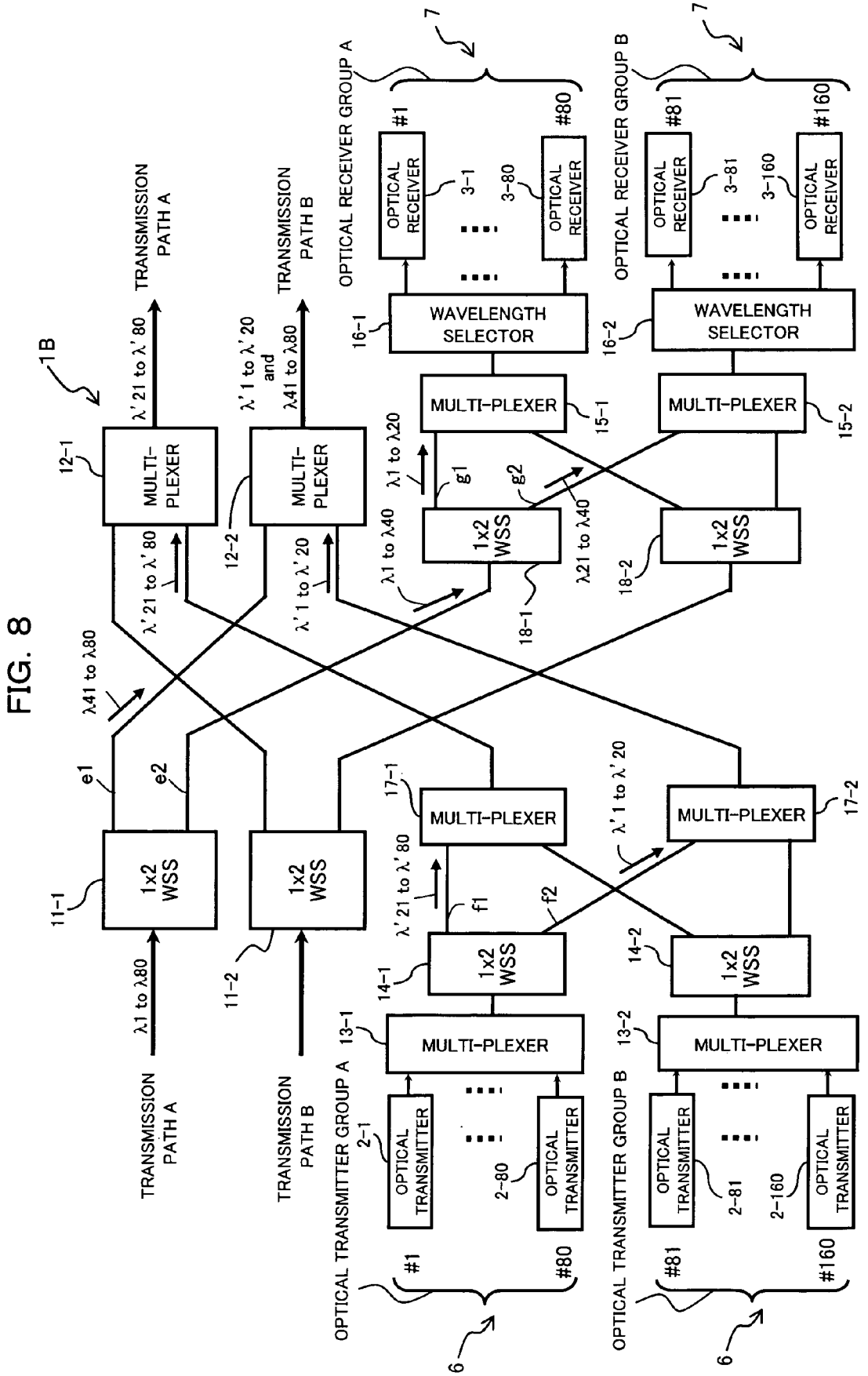
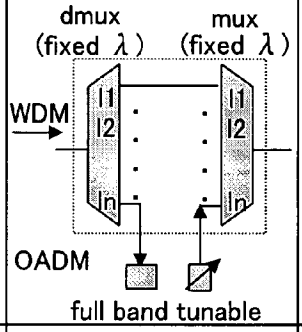
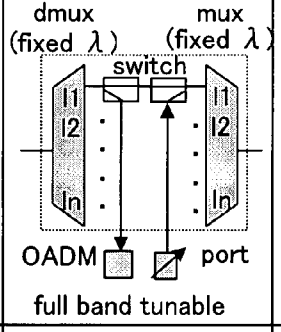
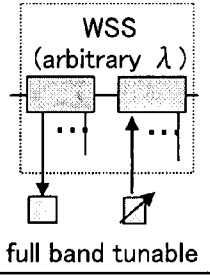

1B
TRANSMISSION PATH A
TRANSMISSION PATH B
λ1 to λ80
λ41 to λ80
λ'21 to λ'80
λ'1 to λ'20
λ'1 to λ'20 and λ41 to λ80
MULTI-PLEXER
1x2 WSS
11-1
11-2
12-1
12-2
e1
e2
f1
f2
g1
g2
13-1
13-2
14-1
14-2
15-1
15-2
16-1
16-2
17-1
17-2
18-1
18-2
OPTICAL TRANSMITTER GROUP A
OPTICAL TRANSMITTER GROUP B
OPTICAL TRANSMITTER
2-1
2-80
2-81
2-160
#1
#80
#81
#160
6
7
OPTICAL RECEIVER GROUP A
OPTICAL RECEIVER GROUP B
OPTICAL RECEIVER
3-1
3-80
3-81
3-160
WAVELENGTH SELECTOR
λ1 to λ40
λ21 to λ40
λ1 to λ20

FIG. 9

Definition and comparison between P/R/DOADM

Name	(1)Passive OADM	(2)Reconfigurable OADM	(3)Dynamic OADM
Configuration (example)			
drop/thru automatically switchable ?	No (manual)	Yes	Yes
ability to add any I into any port	unachievable (should select port)	unachievable (should select port)	achievable
ability to drop any I into any transponder	unachievable	unachievable	achievable
reconnection between OADM and transponder	manual	manual	No necessary

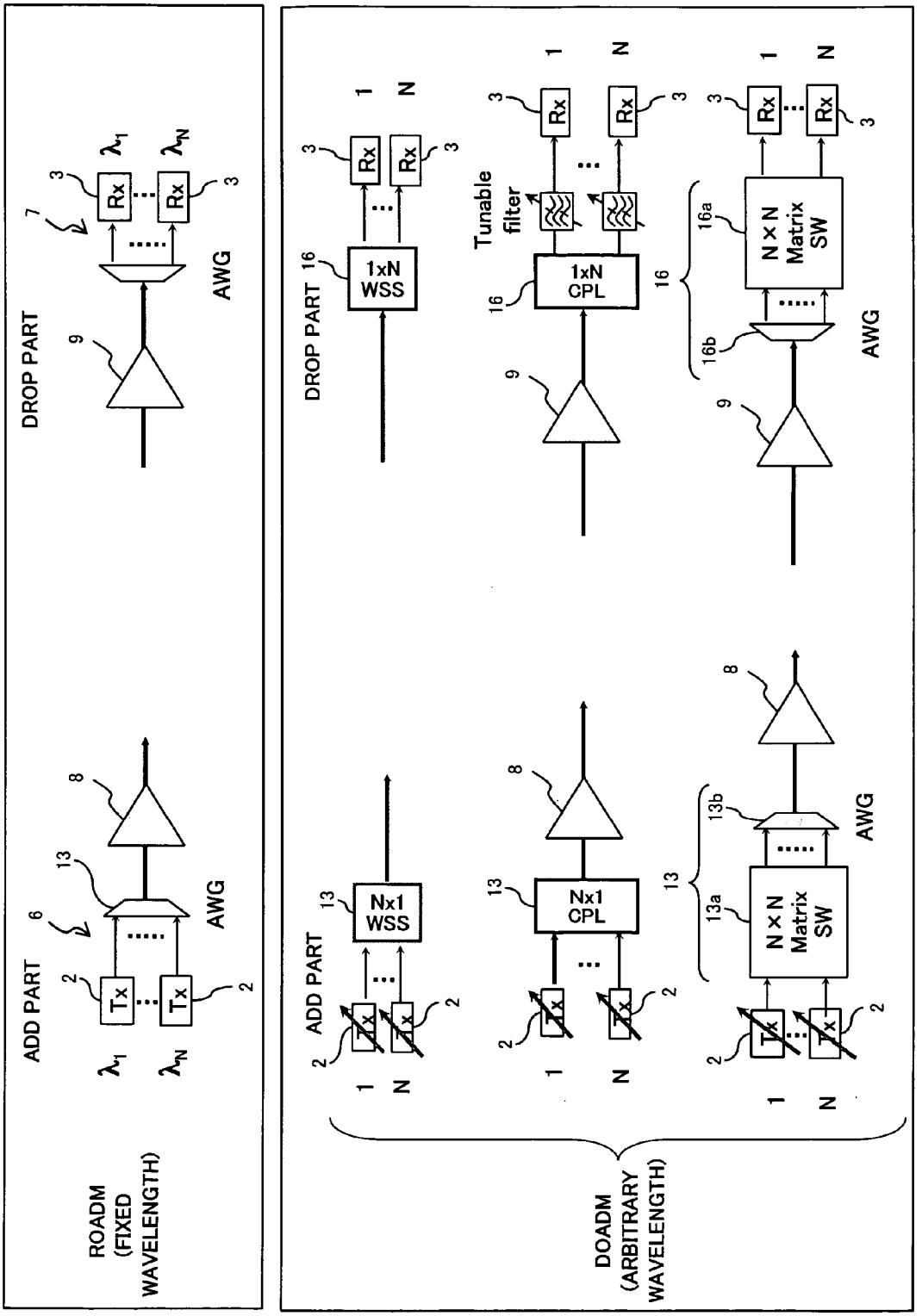


FIG. 10A

FIG. 10B

FIG. 11A

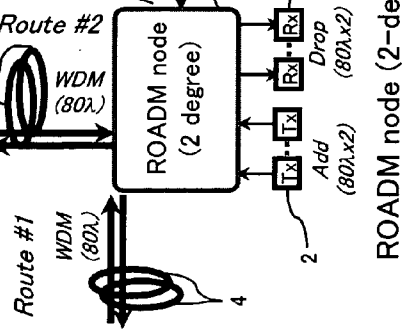


FIG. 11B

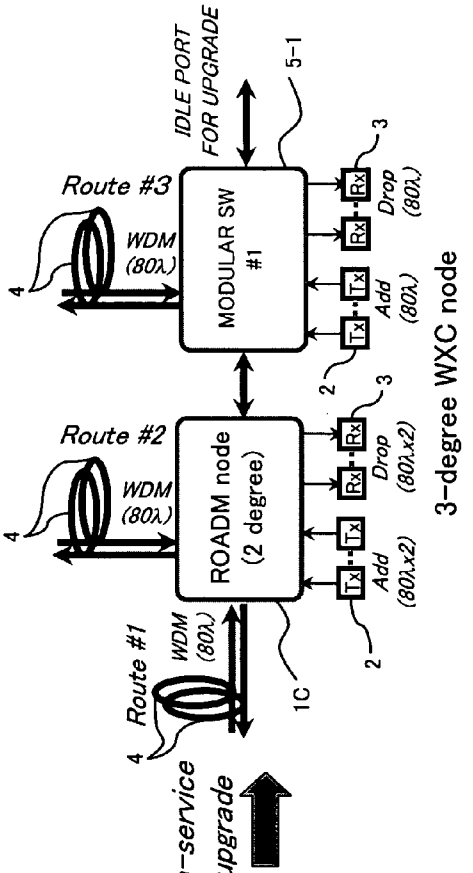


FIG. 11C

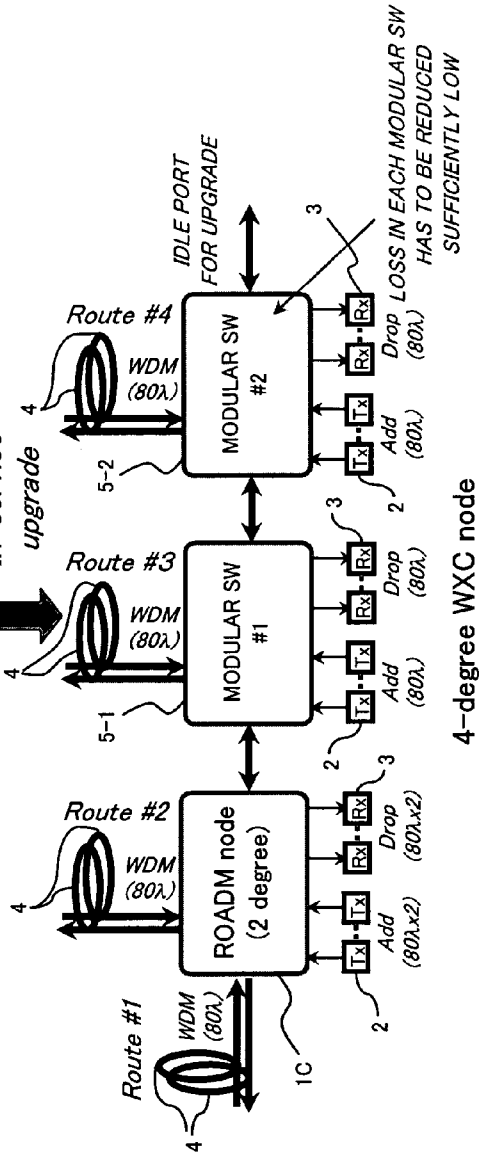


FIG. 12

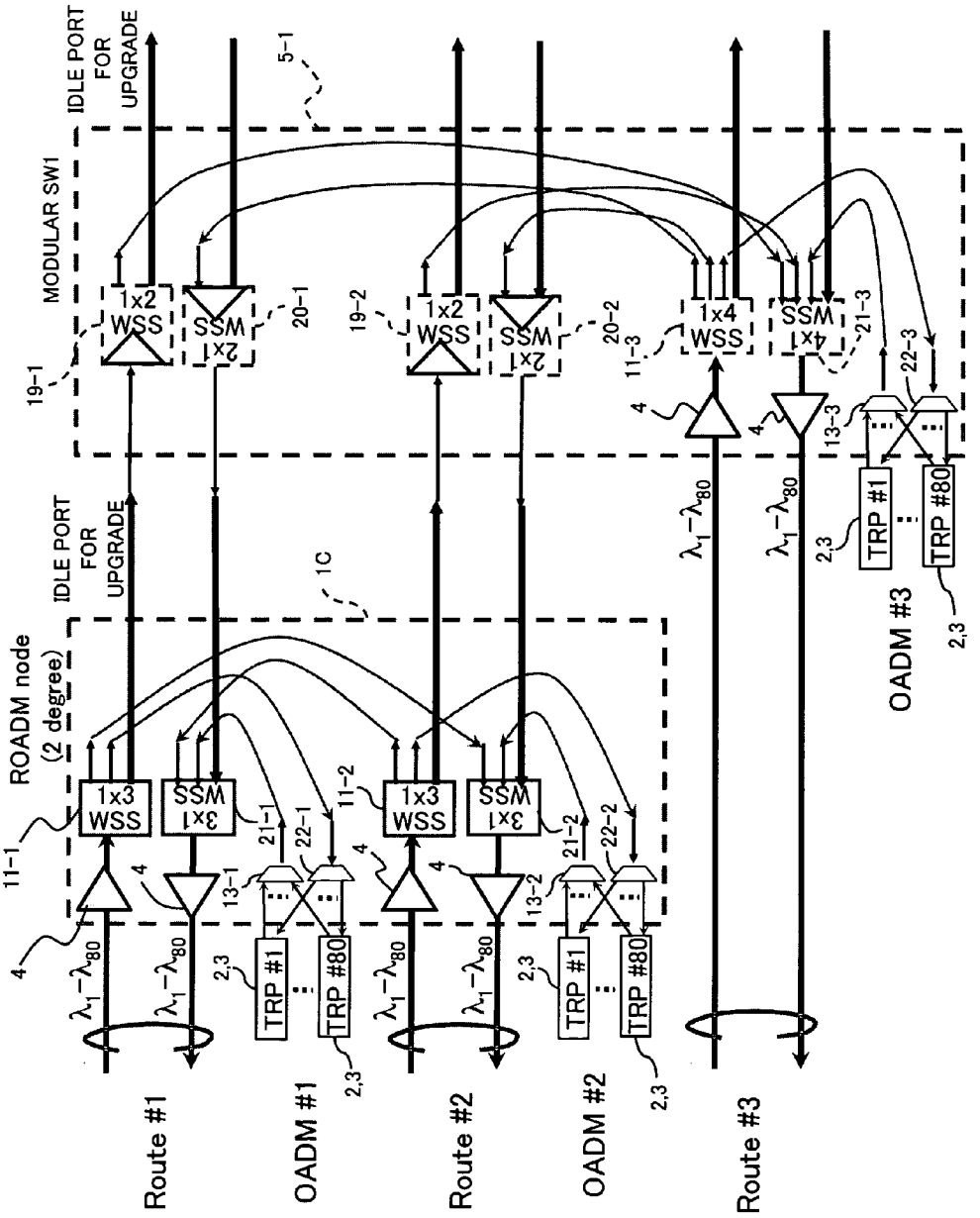

MODULAR SW1
IDLE PORT FOR UPGRADE
5-1
19-1
1x2 WSS
SSM 2x1
20-1
19-2
20-2
11-3
1x4 WSS
SSM 4x1
21-3
22-3
13-3
4
ROADM node (2 degree)
1C
11-1
1x3 WSS
SSM 3x1
21-1
22-1
11-2
21-2
22-2
13-1
13-2
$\lambda_1-\lambda_{80}$
2,3
TRP #1
TRP #80
Route #1
OADM #1
Route #2
OADM #2
Route #3
OADM #3

FIG. 13

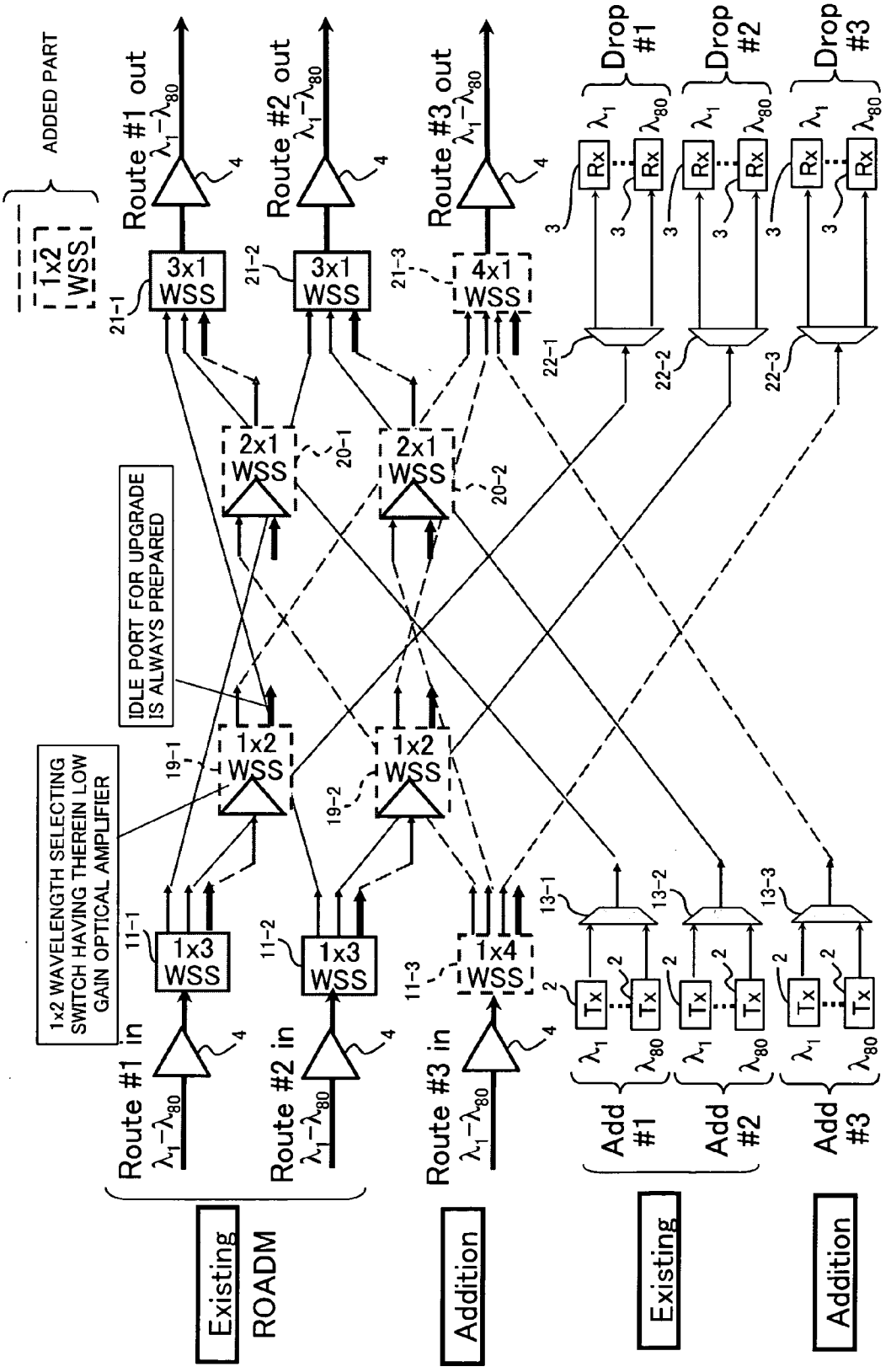

ADDED PART
1x2 WSS
Route #1 out
Route #2 out
Route #3 out
3x1 WSS
4x1 WSS
2x1 WSS
1x2 WSS
1x3 WSS
1x4 WSS
Drop #1
Drop #2
Drop #3
Rx
Tx
IDLE PORT FOR UPGRADE IS ALWAYS PREPARED
1x2 WAVELENGTH SELECTING SWITCH HAVING THEREIN LOW GAIN OPTICAL AMPLIFIER
Route #1 in
Route #2 in
Route #3 in
Add #1
Add #2
Add #3
Existing ROADM
Addition
Existing
Addition

FIG. 14A

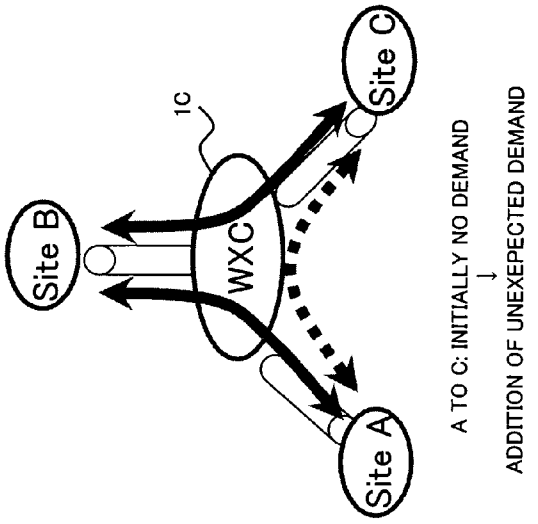


FIG. 14B

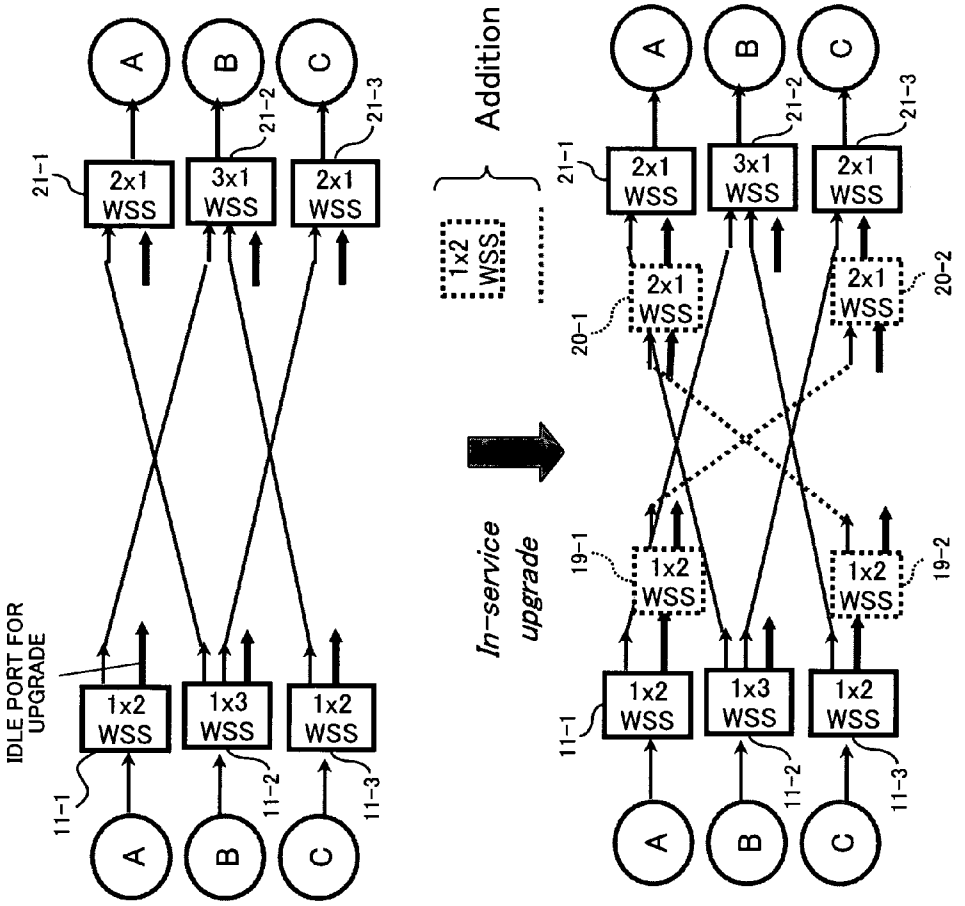


FIG. 14C

FIG. 15

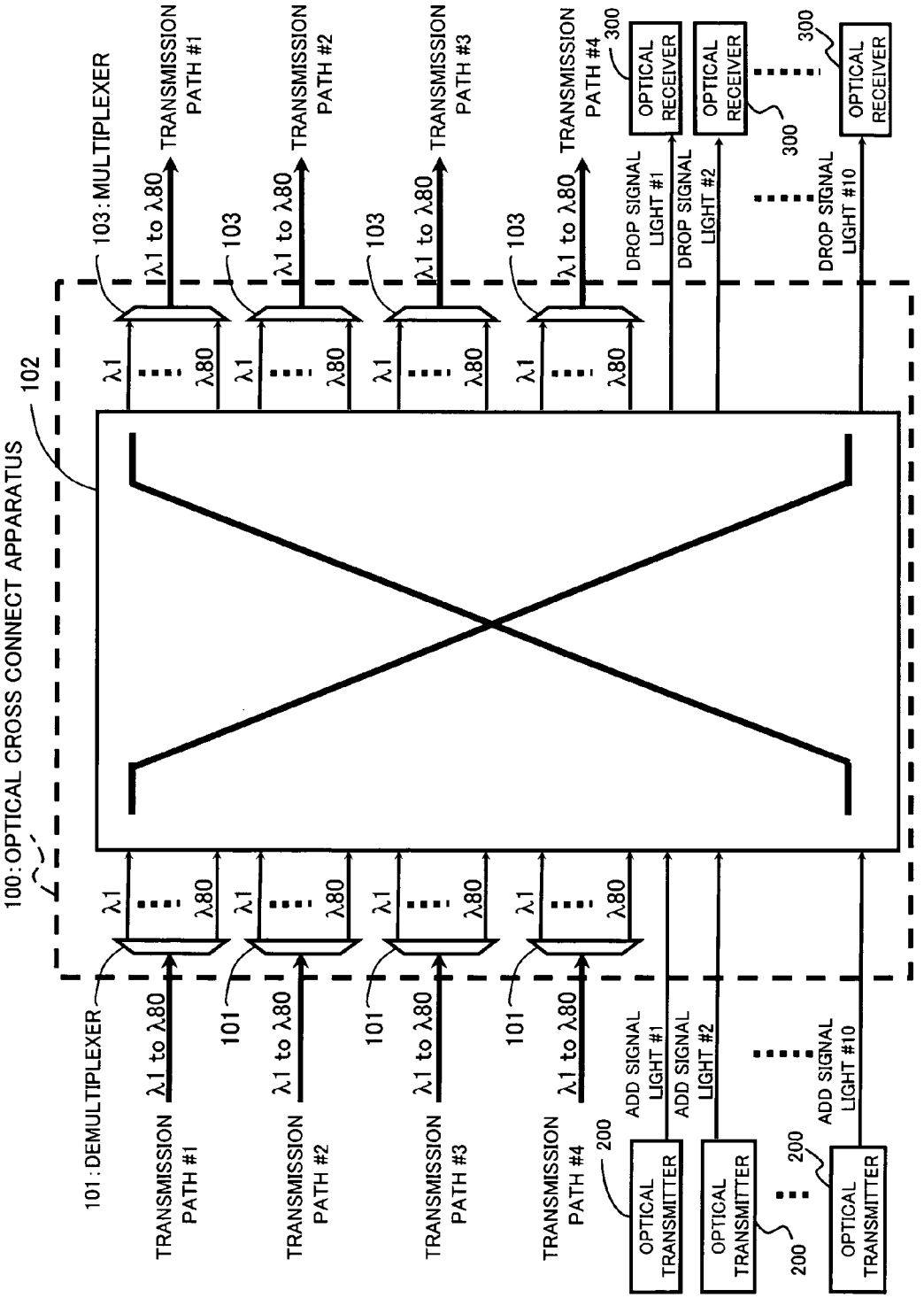

100:OPTICAL CROSS CONNECT APPARATUS
102
101:DEMULTIPLEXER
103:MULTIPLEXER
λ1 to λ80
λ1
λ80
TRANSMISSION PATH #1
TRANSMISSION PATH #2
TRANSMISSION PATH #3
TRANSMISSION PATH #4
101
103
200
300
ADD SIGNAL LIGHT #1
ADD SIGNAL LIGHT #2
ADD SIGNAL LIGHT #10
DROP SIGNAL LIGHT #1
DROP SIGNAL LIGHT #2
DROP SIGNAL LIGHT #10
OPTICAL TRANSMITTER
OPTICAL RECEIVER

FIG. 16A

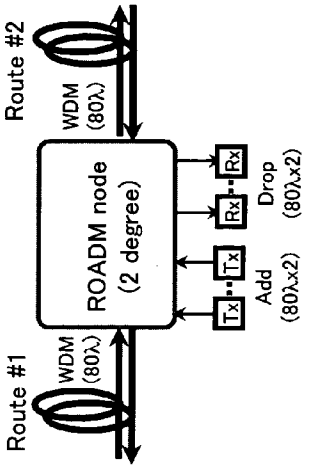


FIG. 16B

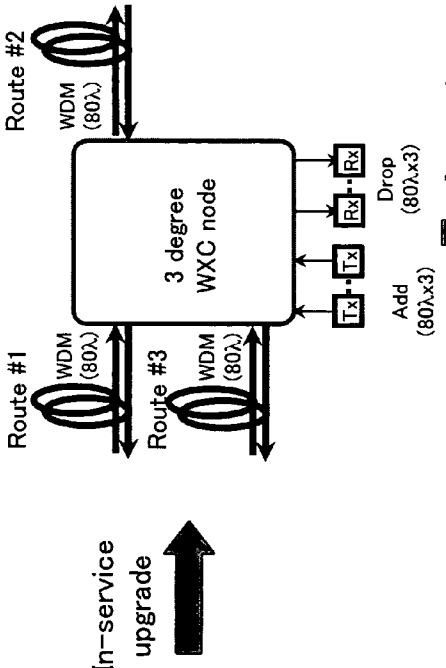


FIG. 16C

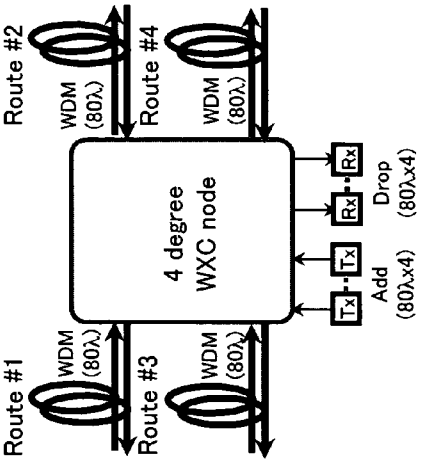
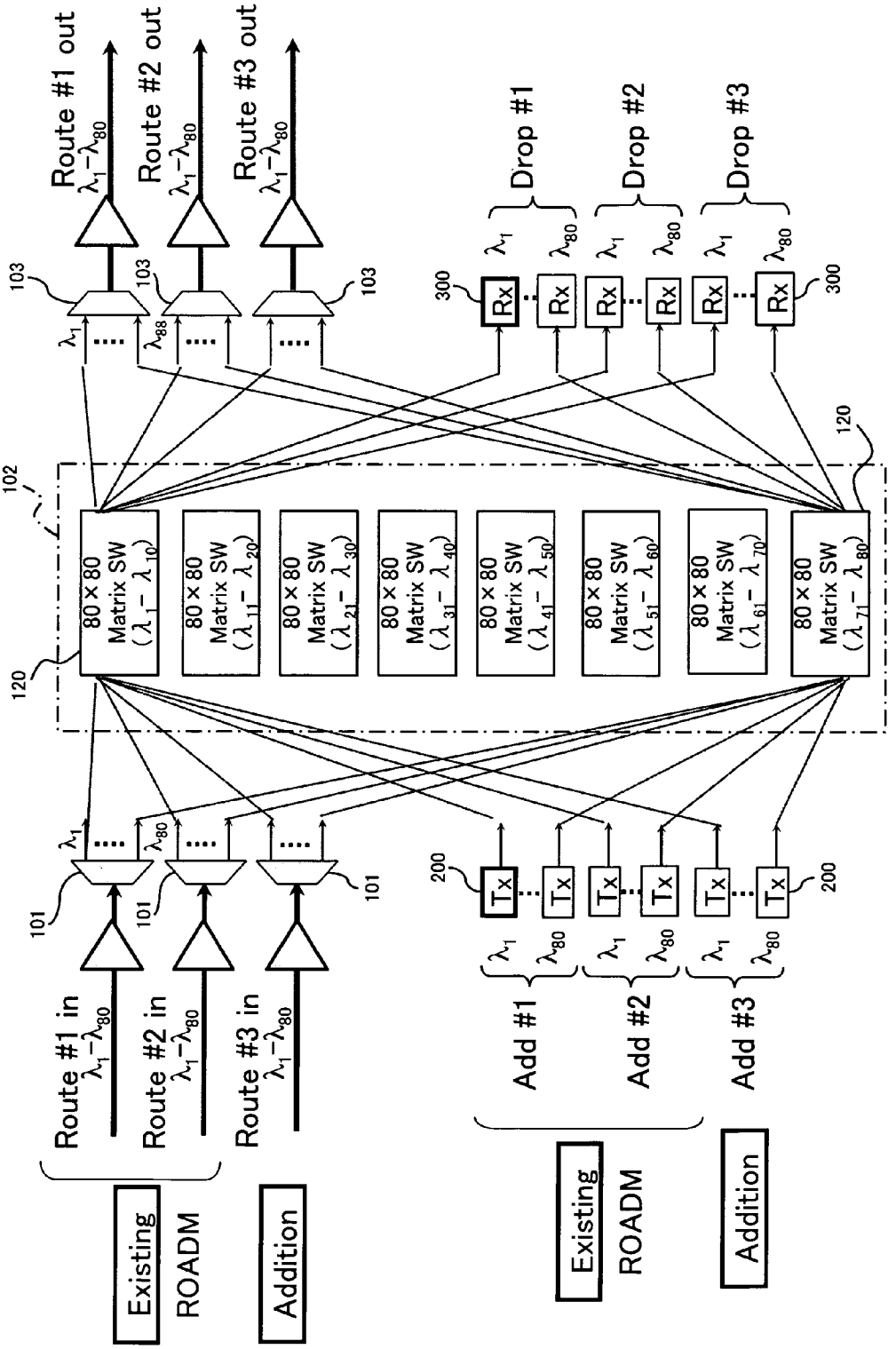


FIG. 17


Route #1 out
Route #2 out
Route #3 out
Drop #1
Drop #2
Drop #3
80×80 Matrix SW
Route #1 in
Route #2 in
Route #3 in
Add #1
Add #2
Add #3
Existing ROADM
Addition
Existing ROADM
Addition

OPTICAL TRANSMITTING APPARATUS, METHOD OF INCREASING THE NUMBER OF PATHS OF THE APPARATUS, AND OPTICAL SWITCH MODULE FOR INCREASING THE NUMBER OF PATHS OF THE APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and hereby claims priority to Japanese Application No. 2004-326556 filed on Nov. 10, 2004 in Japan, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] (1) Field of the Invention

[0003] The present invention relates to an optical transmitting apparatus, a method of increasing the number of paths of the apparatus, and an optical switch module for increasing the number of paths of the apparatus and, more particularly, to a technique suitable for use in an optical transmitting apparatus having an optical cross connecting function and an optical add-drop function.

[0004] (2) Description of Related Art

[0005] In a wavelength division multiplex (WDM) optical transmitting system, an optical cross connect function of changing the destination of input light every wavelength of WDM light and an optical add and drop multiplexing (OADM) function of outputting (adding) add signal light having an arbitrary wavelength to an arbitrary path and branching (dropping) and receiving signal light having an arbitrary wavelength from an arbitrary path are in increasing demand.

[0006] **FIG. 15** is a block diagram showing an example of the configuration of a conventional optical cross connect apparatus (optical transmitting apparatus). An optical cross connect apparatus (hereinbelow, also called a node) **100** shown in **FIG. 15** is an optical cross connect apparatus to/from which WDM signal lights having 80 wavelengths (80 channels) λ1 to λ80 at the maximum are input/output for each of four transmission paths #**1**, #**2**, #**3**, and #**4** and which can branch (drop)/insert (add) signal lights of 10 wavelengths at the maximum. The optical cross connect apparatus **100** has a plurality of (four) demultiplexers **101** provided for the transmission paths (input transmission paths) #**1**, #**2**, #**3**, and #**4**, a switch fabric **102** constructed by using a matrix switch (MXS), and a plurality of (four) multiplexers **103** provided for transmission paths (output transmission paths) #**1**, #**2**, #**3**, and #**4**. In **FIG. 15, 200** denotes optical transmitters for 10 wavelengths each for transmitting signal light (add signal lights #**1** to #**10**) to be added to an arbitrary transmission path #i (where i=1 to 4), and **300** denotes optical receivers for 10 wavelengths each for receiving signal light (drop signal lights #**1** to #**10**) dropped from the arbitrary transmission path #i.

[0007] Each of the demultiplexers **101** has wavelength selectivity and is provided to demultiplex input WDM light (in which 80 waves of λ1 to λ80 are multiplexed at the maximum per transmission path) by wavelength. The switch fabric **102** is a switch capable of transmitting input signal light which is input to any of input ports to any output port except for an output port of the same transmission path. In **FIG. 15**, since WDM signal lights having 80 wavelengths λ1 to λ80 are input/output to/from each of the four transmission paths #**1** to #**4** and signal lights having 10 wavelengths are dropped/added, 330 input ports (=4×80+10) and 330 output ports (total 660 ports) are provided. Each of the multiplexers **103** multiplexes signal lights having 80 wavelengths at the maximum output from each of the output ports of the switch fabric **102** and outputs the resultant light to a corresponding output transmission path #i.

[0008] With such a configuration, in the conventional optical cross connect apparatus **100**, WDM light input from any input transmission path #i or add signal light #x (where x=any of 1 to 10) output from any of the optical transmitters **200** is input to the switch fabric **102** on the wavelength unit basis via a predetermined input port and the destination (output port) is changed on the wavelength unit basis in the switch fabric **102**. The destination is switched to an output transmission path #j (where j is any of 1 to 4 and j≠i) which is different from the input transmission path #i. The signal light after the path has been changed is multiplexed by the multiplexer **103** and output as WDM light to corresponding one of the output transmission paths #**1**, #**2**, #**3** and #**4** or received as dropped signal light #x by any of the optical receivers **300**.

[0009] In such a manner, the conventional optical cross connect apparatus **100** can switch the path of WDM light which is input from an arbitrary input transmission path #i to an arbitrary output transmission path #i on the wavelength unit basis, and add an add signal light #x to the WDM light to the arbitrary output transmission path #i or drop signal light #x having arbitrary wavelength of the WDM light from an arbitrary input transmission path #i.

[0010] Another optical cross connect apparatus is disclosed in, for example, Japanese Patent Application Laid-Open No. H8-237221 (Patent Document 1). The conventional technique of Patent Document 1 is directed to increase flexibility in expansion of the number of input/output highways and the number of input/output links and to facilitate switching of a signal channel. In the conventional technique, as shown in FIG. 1 of Patent Document 1, the apparatus includes: N1 pieces of 1-input M-output optical demultiplexers for separating light signals of N1 series into M signal channels; N1 pieces of M-input (N1+N2)-output optical switches for allocating the signal channels to output destinations (highways) of the N1 series or reception (drop) destinations of N2 series; N2 pieces of M-input N1-output optical switches for allocating signal channels transmitted from an optical signal (add signal light) transmitter to output destinations (highways) of the N1 series; N1 pieces of (N1+N2)-input 1-output optical combiners for combining outputs of the optical switches for each of output destinations of the N1 series; a wavelength converting circuit disposed between the optical signal transmitter and the M-input N1-output optical switches; and N2 pieces of N1-input M-output wavelength selection optical switches for allocating outputs of the M-input (N1+N2)-output optical switches to M receivers (drop destinations) by wavelength selection.

[0011] The configuration corresponds to a configuration obtained by constructing the switch fabric **102** shown in **FIG. 15** by N1 pieces of M-input (N1+N2)-output optical switches, N2 pieces of M-input N1-output optical switches,

N1 pieces of (N1+N2)-input 1-output optical combiners, and N2 pieces of N1-input M-output wavelength selection optical switches.

[0012] With the configuration, in the conventional technique, as described in the columns **0023** to **0025**, optical signals of the N1 series whose wavelengths are multiplexed are separated into different signal channels and, after that, by using the N1 pieces of M-input (N1+N2)-output optical switches, the signal channels are allocated to the output destinations of the N1 series or the receive (drop) destinations of the N2 series. On the other hand, optical signals of the N2 series to be transmitted (added) are subjected to a wavelength converting process by the wavelength converting circuit every signal channel, and the processed signals are allocated to the output destinations (highways) of the N1 series. The signal channels allocated to the output destinations of the N1 series are combined every destination. At this time, the wavelength of a signal channel to be transmitted (added) can be arbitrarily set, so that the path of the signal channel can be easily switched.

[0013] With respect to the signal channels allocated as the receive (drop) destinations of the N2 series from the N1 pieces of M-input (N1+N2)-output optical switches, a signal channel having an arbitrary wavelength on an arbitrary input optical highway can be output to an arbitrary output link without causing wavelength collision by wavelength selection by the N1-input M-output wavelength selection optical switch. Consequently, it becomes unnecessary to consider wavelength dependency in an output link at the time of setting the wavelength of a signal channel.

[0014] In such a manner, switch of signal channels between an input and an output (optical cross connect) and switch of a receive (drop) signal channel and a transmit (add) signal channel (OADM) can be simultaneously performed.

[0015] The conventional optical cross connect apparatus has, however, the following problems.

(1) Problems on the Number of Ports, Cost, and Size in the Conventional Node Configuration

[0016] In the optical cross connect apparatus described with reference to **FIG. 15**, signal light having a single wavelength is input/output to/from each of input/output ports of the switch fabric **102** (MXS). Therefore, when the number of wavelengths of signal light to be input/output from/to the optical cross connect apparatus increases, the number of input/output ports of the switch fabric **102** becomes very large. Accordingly, the size of the whole apparatus becomes large and the number of optical fiber patch cords to be connected to the switch fabric **102** also becomes enormous. A problem occurs such that it becomes very inconvenient to house and manage the optical fiber patch cords.

[0017] Further, to address future increase in the number of input/output transmission paths and drop/add signal light, input/output ports of the maximum predictable wavelengths have to be prepared. Therefore, an enormous switch fabric **102** is necessary from the initial operation. For example, in the configuration shown in **FIG. 15**, WDM lights having 80 wavelengths at the maximum are input/output to/from each of the four transmission paths #**1** to #**4** and signal lights of 10 wavelengths are dropped/added. Consequently, each of the number of input/output ports necessary for the switch fabric **102** (MXS) and the number of optical fiber patch cords connected to the switch fabric **102** (MXS) is as enormous as **660**. For example, if there is the possibility that one input/output transmission path will be added in the future, **160** input/output ports are necessary as spare ports from the start of use of the apparatus.

[0018] The technique of Patent Document 1 has points similar to those points. For example, if the number of input/output wavelengths (M) increases, the number of input/output ports necessary for the optical switches and the optical combiners also increases, so that the apparatus scale and cost increase. In particular, since the number of input/output ports which can be provided for the optical switches and optical combiners is limited in the present techniques, in the case where optical signals of tens of wavelengths are multiplexed per highway, the technique cannot be realized. Moreover, also in the case of addressing future increase in the number of input/output transmission paths and increase in drop/add signal lights, input/output ports of the predictable maximum number of wavelengths have to be prepared for spare (unused) optical switch and optical combiner, so that the apparatus becomes large-scaled and expensive from the initial operation.

(2) Problems on Increase in the Number of Paths (Transmission Paths) In-Service in Conventional Node Configuration

[0019] The users strongly demand for in-service upgrading (upgrading which does not interrupt signals being transmitted) from an ROADM node (Reconfigurable OADM node of 2 degrees (where 2 degrees denotes that the number of transmission paths to be handled is two): a node for remotely switching between a transmission signal and drop/add signal light every wavelength) as shown in **FIG. 16A** to a wavelength cross connect (WXC) node of 3 degrees as shown in **FIG. 16B**, or from 3 degrees to a WXC node of four or higher degrees as shown in **FIG. 16C**.

[0020] However, in the conventional node configuration shown in **FIG. 15**, as described above, the number of degrees to be finally requested is predicted, and the switch fabric **102** having the maximum configuration which can deal with signals at the expected number of degrees has to be prepared from the initial operation. For example, as shown in **FIG. 17**, in the case where a matrix switch **120** of 80 inputs and 80 outputs (80×80) is used and the final number of degrees is expected as four, eight signal lights of one wavelength exists (4 (for transmission signal)+4 (in the case of 100% add-drop)), 10 wavelengths (80÷8) are allocated to one matrix switch **120**.

[0021] When it is assumed that the number of degrees upon initial introduction is two, 40 input/output ports (=[(2 (transmission signals)+2 (for add/drop signals)]×10 wavelengths) of the matrix switch **120** are used out of 80 input/output ports of one matrix switch **120** but the remaining 40 input/output ports become unused (spare) ports. That is, the same cost as that in the final form is necessary at the initial introduction. Moreover, in the case where upgrading to the number of degrees over expectation is requested, the request cannot be addressed.

[0022] The technique of Patent Document 1 also has the same problem. It is necessary to predict the number of

degrees finally requested and preliminarily prepare spare optical switches and optical combiners of the maximum configuration capable of handling signals of the predicted number of degrees.

SUMMARY OF THE INVENTION

[0023] The invention has been achieved in consideration of such problems and an object of the invention is to realize flexible function expansion of an optical transmitting apparatus while largely reducing the number of wires (optical fiber patch cords) (reducing the size of the apparatus) necessary in an optical transmitting apparatus dealing with a plurality of transmission paths such as an optical cross connect apparatus and largely reducing the number of spare ports required for future increase in the number of transmission paths.

[0024] In order to achieve the above-mentioned object, the optical transmitting apparatus of the present invention is an apparatus to which first to K-th (where K denotes an integer of 2 or larger) input transmission paths and first to K-th output transmission paths are connected and which has dropping means, and comprises K pieces of optical path switching means each having an input port connected to said k-th (where k denotes an integer from 1 to K) input transmission path, and K pieces of output ports. The optical transmitting apparatus is characterized in that the dropping means has K pieces of input ports connected to said first to K-th optical path switching means, and an output port, said K pieces of output ports of said optical path switching means whose input port is connected to said k-th input transmission path are connected to said first to K-th output transmission paths except for the k-th output transmission path and to the k-th input port of said dropping means, and said optical path switching means and said dropping means output light of wavelength which is part or all of wavelength division multiplex light received from said input port from a specific output port, and can output light having a wavelength different from that of the light output from said specific output port from an output port different from said specific output port.

[0025] Further, the optical transmitting apparatus of the present invention is an apparatus to which first to K-th (where K denotes an integer of 2 or larger) input transmission paths and first to K-th output transmission paths are connected and which has D pieces (where D denotes a natural number) of dropping means, and comprises K pieces of optical path switching means each having an input port connected to said k-th (where k denotes an integer from 1 to K) input transmission path, and K pieces of output ports, and K pieces of drop light switching means each having an input port and D pieces of output ports connected to the first to said D-th dropping means. The optical transmitting apparatus is characterized in that said K pieces of output ports of said optical path switching means whose input port is connected to said k-th input transmission path are connected to said first to K-th output transmission paths except for the k-th output transmission path and the input port of said dropping means, and said optical path switching means and said dropping light switching means output light of wavelength which is part or all of wavelength division multiplex light received from said input port from a specific output port and can output light having wavelength different from that of the light output from said specific output port from an output port different from said specific output port.

[0026] Moreover, as the other configuration of the optical transmitting apparatus of the present invention, the apparatus comprises optical path switching means having a plurality of input ports connected to a plurality of input optical transmission paths for transmitting wavelength division multiplex signal light (WDM light) and a plurality of output ports connected to a plurality of output optical transmission paths for transmitting WDM light, capable of selecting signal light of one or more wavelength included in the WDM light received from any of the input ports and outputting the selected signal light from any of the outports, add wavelength output means which combines add signal light of a plurality of wavelengths to obtain combined signal light and selectively couples add signal light having one or more wavelengths included in the combined signal light, as signal light to be multiplexed to WDM light to any of the output optical transmission paths, to any of the output ports of the optical path switching means, and drop wavelength output means which selectively receives and combines the signal light having one or more wavelengths included in the WDM light input to each of the input ports of the optical path switching means and selectively outputs signal light included in the combined signal light on a wavelength unit basis.

[0027] The optical transmitting apparatus is an apparatus to which WDM light of the maximum N wavelengths (where N denotes an integer of 2 or larger) is input from each of K pieces (where K denotes an integer of 2 or larger) of input optical transmission paths and which outputs WDM light of the maximum N wavelengths to each of the K pieces of output optical transmission paths. When the minimum integer of integers M satisfying the relation of $M \geqq I_add/N$ where wavelength of add signal light to be output to any of the output optical transmission paths is set as I_add and wavelength of drop signal light to be dropped from any of the input optical transmission paths is set as I_drop is M_add, and the minimum integer of integers M' satisfying the relation of $M' \geqq I_drop/N$ is M_drop, the optical path switching means comprises K pieces of $1\times(K+M_drop-1)$ wavelength selecting switches provided for the K pieces of input optical transmission paths and selectively outputting signal light of one or more arbitrary wavelengths out of the WDM light from any of the $(K+M_drop-1)$ output ports at the minimum, and K pieces of $(K+M_add-1)$-input 1-output multiplexers provided for the K pieces of output optical transmission paths and having $(K+M_add-1)$ input ports at the minimum and one output port. To one of the $1\times(K+M_drop-1)$ wavelength selecting switches, one of the input ports of $(K-1)$ pieces of $(K+M_add-1)$-input 1-output multiplexers provided for the $(K-1)$ pieces of output optical transmission paths different from the input optical transmission path for which the $1\times(K+M_drop-1)$ wavelength selecting switch is provided is connected. The add wavelength output means has M_add pieces of add wavelength multiplexing and selecting units each of which is connected to one of the input ports of the K pieces of $(K+M_add-1)$-input 1-output multiplexers, multiplexes the add signal light of N wavelengths at the maximum, and selectively outputs add signal light of one or more arbitrary wavelengths to any of the K pieces of $(K+M_add-1)$-input 1-output multiplexers. In addition, the drop wavelength output means has M_drop pieces of drop wavelength multiplexing and selecting units each of which is connected to one of the output ports of the K pieces of $(K+M_drop-1)$ wavelength select-

ing switches, multiplexes outputs of the K pieces of 1×(K+M_drop−1) wavelength selecting switches, and selectively outputs drop signal light having arbitrary wavelength.

[0028] Further, the add wavelength multiplexing and selecting unit can be configured, for example, by comprising an add signal light multiplexer for multiplexing the add signal light, and a 1×K wavelength selecting switch connected to one of the input ports of each of the K pieces of (K+M_add−1)-input 1-output multiplexer and selectively outputting signal light having one or more arbitrary wavelengths included in output light of the add signal light multiplexer to one of the input ports of each of the K pieces of (K+M_add−1)-input 1-output multiplexers.

[0029] Moreover, the drop wavelength multiplexing and selecting unit can be configured by comprising a drop signal light multiplexer connected to each of the output ports of the K pieces of 1×(K+M_drop−1) wavelength selecting switches and multiplexing outputs of the K pieces of 1×(K+M_drop−1) wavelength selecting switches, and a wavelength selector for selectively outputting signal light having arbitrary wavelength included in output light of the drop signal light multiplexer.

[0030] Moreover, the optical transmitting apparatus is an apparatus to which WDM light of the maximum N wavelengths (where N denotes an integer of 2 or larger) is input from each of K pieces of (where K denotes an integer of 2 or larger) input optical transmission paths and which outputs WDM light of the maximum N wavelengths to each of the K pieces of output optical transmission paths. When the minimum integer of integers M satisfying the relation of M≧I_add/N where wavelength of add signal light to be output to any of the output optical transmission paths is set as I_add and wavelength of drop signal light to be dropped from any of the input optical transmission paths is set as I_drop is M_add, and the minimum integer of integers M' satisfying the relation of M'≧I_drop/N is M_drop,

[0031] the optical path switching means comprises K pieces of 1×K wavelength selecting switches provided for the K pieces of input optical transmission paths and selectively outputting signal light of one or more arbitrary wavelengths out of the WDM light from any of K output ports as the minimum, and K pieces of K-input 1-output multiplexers provided for the K pieces of output optical transmission paths and having K input ports at the minimum and one output port. To one 1×K wavelength selecting switch, one of the input ports of (K−1) pieces of K-input 1-output multiplexers provided for the (K−1) pieces of output optical transmission paths different from the input optical transmission path for which the 1×K wavelength selecting switch is provided is connected. The add wavelength output means has M_add pieces of add wavelength multiplexing and selecting units each having K pieces of output ports at the minimum, multiplexing the add signal light of the N wavelengths at the maximum, and selectively outputting add signal light having arbitrary one or more wavelengths from the output ports, and K pieces of M_add-input 1-output multiplexers each having M_add pieces of input ports and one output port. Each of the input ports of the M_add-input and 1-output multiplexers is connected to one of the output ports of the M_add pieces of add wavelength multiplexing and selecting units, and the output port of the M_add-input 1-output multiplexer is connected to one of the input ports of the K-input 1-output multiplexer. In addition, the drop wavelength output means has K pieces of 1×M_drop wavelength selecting switches each of which is connected to one of the output ports of the 1×K wavelength selecting switch and outputting signal light having one or more arbitrary wavelengths out of output light from the 1×K wavelength selecting switch from any of the M_drop pieces of output ports at the minimum, and M_drop pieces of drop wavelength multiplexing and selecting units each connected to one of output ports of the K pieces of 1×M_drop wavelength selecting switches, multiplexing outputs of the K pieces of 1×M_drop wavelength selecting switches, and selectively outputting drop signal light having arbitrary wavelength.

[0032] The add wavelength multiplexing and selecting unit can be configured by comprising an add wavelength multiplexer for multiplexing the add signal light, and a 1×K wavelength selecting switch connected to one of the input ports of each of the K pieces of the M_add-input 1-output multiplexers and selectively outputting signal light having one or more arbitrary wavelengths included in output light of the add wavelength multiplexer to one of the input ports of each of the K pieces of M_add-input 1-output multiplexers.

[0033] On the other hand, the drop wavelength multiplexing and selecting unit can be configured, for example, by comprising a K-input 1-output drop wavelength multiplexer for multiplexing outputs from one of the output ports of each of the K pieces of 1×M_drop wavelength selecting switches, and a wavelength selector for selectively outputting signal light having arbitrary wavelength included in output light of the drop signal light multiplexer.

[0034] Next, the method of adding a path for an optical transmitting apparatus of the present invention is a method in which the number of transmission paths is increased by connecting an optical switch module having wavelength selecting switches of the number required in accordance with the number of transmission paths to be increased to an optical transmitting apparatus having optical path switching means by using an idle port of the wavelength selecting switches in the optical path switching means, and the optical path switching means is connected to a plurality of transmission paths for transmitting WDM light and is constructed by a combination of a plurality of wavelength selecting switches to output signal light having any wavelength included in the WDM light from a transmission path to another transmission path.

[0035] Preferably, the wavelength selecting switch in the optical path switching means is preliminarily provided with an idle port for adding at least one path.

[0036] Further, the number of transmission paths can be further increased by preliminarily providing the wavelength selecting switch in the optical switch module with at least one idle port for adding a path so as to prepare for further increase in the number of transmission paths, and connecting another optical switch module by using the idle port.

[0037] Further, the optical switch module may have one or more 1-input k-output (where k denotes an integer of 2 or larger) wavelength selecting switches and one or more k-input 1-output wavelength selecting switch, the input port of said 1-input k-output wavelength selecting switch and the

output port of said k-input 1-output wavelength selecting switch may be connected to the idle port of the wavelength selecting switch in the optical wavelength selecting means or an add transmission path, and at least one of output ports of said 1-input k-output wavelength selecting switch and at least one of input ports of said k-input 1-output wavelength selecting switch may be set as idle ports for connecting said another optical switch module.

[0038] Further, the optical switch module may be provided with an optical amplifier for amplifying signal light sent via a plurality of wavelength selecting switches.

[0039] Moreover, the optical transmitting apparatus of the present invention is an apparatus having optical path switching means connected to a plurality of transmission paths for transmitting WDM light and constructed by combining a plurality of wavelength selecting switches to output signal light having any wavelength included in the WDM light from a transmission path to another transmission path. The optical transmitting apparatus is characterized in that the wavelength selecting switch in the optical path switching means is provided with an idle port for connecting an optical switch module constructed by including wavelength selecting switches of the number required in accordance with the number of transmission paths to be added.

[0040] The optical switch module for adding a path for an optical transmitting apparatus of the present invention is an apparatus having optical path switching means connected to a plurality of transmission paths for transmitting WDM light and constructed by combining a plurality of wavelength selecting switches to output signal light having any wavelength included in the WDM light from a transmission path to another transmission path, and comprises wavelength selecting switches of the number necessary in accordance with the number of transmission paths to be added. The optical switch module is characterized in that the wavelength selecting switches are connected idle ports of the wavelength selecting switches in the optical path switching means in the optical transmitting apparatus.

[0041] The wavelength selecting switch in the optical switch module may be provided with an idle port for adding a path so as to prepare for further increase in the number of transmission paths, and connecting another optical switch module by using the idle port.

[0042] Further, the optical switch module for adding a path to an optical transmitting apparatus comprises one or more 1-input k-output wavelength selecting switches (where k denotes an integer of 2 or larger) and k-input 1-output wavelength selecting switches as the wavelength selecting switch in the optical switch module. The optical switch module is characterized in that the input port of said 1-input k-output wavelength selecting switch and the output port of said k-input 1-output wavelength selecting switch may be connected to the idle port of the wavelength selecting switch in the optical wavelength selecting means in the optical transmitting apparatus or an add transmission path, and at least one of the output ports of said 1-input k-output wavelength selecting switch and at least one of the input ports of said k-input 1-output wavelength selecting switch may be provided as idle ports for connecting said another optical switch module.

[0043] According to the invention, the following effects and advantages are obtained.

[0044] (1) Since signal lights having one or more wavelengths included in WDM light input from any of input ports are selected and output from any of output ports in the optical path switching means, a transmission path of signal light having an arbitrary wavelength included in the WDM light from a transmission path can be changed to a different path without demultiplexing the WDM light every wavelength unlike the conventional technique, and the number of ports necessary for the optical path switching means can be largely reduced.

[0045] (2) By the add wavelength output means, add signal lights of plural wavelengths are multiplexed and an add signal light having one or more wavelengths included in the multiplexed signal light can be selectively connected as signal light to be multiplexed to the WDM light to any output light transmission path to any of output ports of the optical path switching means. By the drop wavelength output means, signal light having one or more wavelengths included in WDM light to be input to any of input ports of the optical path switching means is selectively received and multiplexed and signal light included in the multiplexed signal light can be selectively output on the wavelength unit basis. Thus, the number of optical wires (the number of fiber patch cords) necessary in the optical transmitting apparatus can be largely reduced as compared with the conventional technique.

[0046] (3) Further, each of the number of optical wires (input ports of a multiplexer) occupied by add signal light for the output ports of the optical path switching means and optical wires (output ports of a wavelength selection switch) occupied by drop signal light for the input ports of the optical path switching means can be set to one at the minimum irrespective of the wavelength multiplexing number of the WDM light. Consequently, even when the wavelength multiplexing number increases, an optical device such as the multiplexer having the necessary number of ports can be sufficiently realized by the present technical level and, moreover, it largely contributes to realization of the optical transmitting apparatus.

[0047] Specifically, by allocating one of the output ports of the optical path switching means irrespective of the number of output ports of the drop signal light, a path can be switched and drop-add can be performed. Therefore, without increasing the number of output ports of the optical path switching means, the number of ports of the drop signal light can be increased.

[0048] (4) In the case where future increase in the number of transmission paths and the number of drop/add signal light wavelengths is expected, by setting the number of output ports of the wavelength selection switch and the number of input ports of a multiplexer to be larger than K, for example, by setting the number of output ports of the wavelength selection switch and the number of input ports of the multiplexer to (K+K') ports (that is, by providing K' pieces of spare ports), the transmission path number can be increased by K' pieces or the drop/add signal light can be increased by N×K' pieces. That is, future functional expansion of the apparatus can be addressed by the spare port number overwhelmingly smaller than that of the conventional configuration.

[0049] (5) Further, each of the number of output ports of a wavelength selection switch provided for each of a plu-

rality of transmission paths and the number of input ports of a multiplexer can be set to constant (K) without depending on the number of drop/add signal light wavelengths. Consequently, drop/add signal light can be increased without exerting an influence on, at least, signal lights related to a path change. Even if the number of drop/add signal light wavelengths increase, each of the number of output ports of the wavelength selection switch and the number of input ports of the multiplexer can be suppressed to the number K of transmission paths. Therefore, the optical devices each having the necessary number of ports can be sufficiently realized by the present technical level and, moreover, it largely contributes to realization of the optical transmitting apparatus.

[0050] (6) By connecting an optical switch module constructed by wavelength selection switches of the necessary number according to the number of transmission paths to be increased to an optical transmitting apparatus having optical path switching means constructed by combining a plurality of wavelength selection switches by using an idle port of the wavelength selection switch in the optical path switching means, without preparing spare optical devices such as wavelength selection switches and the enormous number of spare ports which are necessary for a predicted final form from initial introduction, the number of transmission paths can be increased (upgrading can be performed). Thus, the initial introduction cost of the optical transmitting apparatus can be largely reduced, and free increase in the number of transmission paths can be flexibly addressed without exerting an influence on the transmission of existing signal lights (namely, without service interruption).

[0051] (7) Particularly, by preliminarily providing at least one idle port for adding a path for the wavelength selection switch in the optical path switching means, while suppressing the number of input/output ports necessary for the optical path switching means in association with increase in the number of transmission paths to the minimum, increase in the number of transmission paths can be realized. By providing at least one idle port for adding a path in advance for further increase in the number of transmission paths for the wavelength selection switch in the optical switch module and connecting another optical switch module by using the idle port, the number of transmission paths can be easily increased.

[0052] (8) By providing the optical switch module with an optical amplifier for amplifying signal light passing through a plurality of wavelength selection switches, an optical loss of the signal light passing through the wavelength selection switches in multiple stages due to addition of the optical switch module can be compensated. Therefore, even when the number of transmission paths is increased due to addition of the optical switch module, necessary transmission characteristics of the signal light can be assured.

BRIEF DESCRIPTION OF THE DRAWINGS

[0053] **FIG. 1** is a block diagram showing the configuration of an optical cross connect apparatus (optical transmitting apparatus) of a first embodiment of the invention.

[0054] **FIG. 2** is a block diagram showing an example of the configuration of a wavelength selection switch illustrated in **FIG. 1**.

[0055] **FIG. 3** is a block diagram showing an example of the configuration of the wavelength selection switch illustrated in **FIG. 1**.

[0056] **FIG. 4** is a block diagram showing an example of the configuration of a wavelength selector illustrated in **FIG. 1**.

[0057] **FIG. 5** is a block diagram showing the configuration in the case where the optical cross connect apparatus illustrate in **FIG. 1** has the number of transmission paths K=2, the wavelength multiplexing number N=80, the number of add signal light wavelengths m=80, and the number of drop signal light wavelengths n=80.

[0058] **FIG. 6** is a block diagram showing the configuration in the case where the optical cross connect apparatus illustrate in **FIG. 1** has the number of transmission paths K=4, the wavelength multiplexing number N=80, the number of add signal light wavelengths m=10, and the number of drop signal light wavelengths n=10.

[0059] **FIG. 7** is a block diagram showing a first modification of the optical cross connect apparatus illustrated in **FIG. 1**.

[0060] **FIG. 8** is a block diagram showing a second modification of the optical cross connect apparatus illustrated in **FIG. 1**.

[0061] **FIG. 9** is a diagram for explaining modes (POADM, ROADM, and DOADM) of the configuration of the optical cross connect apparatus (OADM).

[0062] **FIG. 10A** is a block diagram showing an example of the configuration of an add part and a drop part in the case of the POADM.

[0063] **FIG. 10B** is a block diagram showing an example of the configuration of an add part and a drop part in the case of the DOADM.

[0064] **FIGS. 11A** to **11**C are diagrams showing images of an optical node in-service upgrading method (method of increasing the number of paths) according to a second embodiment of the invention.

[0065] **FIG. 12** is a block diagram showing the configuration of an optical node and a modular switch for explaining a concrete example of the optical node in-service upgrading method of the second embodiment.

[0066] **FIG. 13** is a block diagram showing the configuration of the optical node and the modular switch for explaining a concrete example of the optical node in-service upgrading method of the second embodiment.

[0067] **FIGS. 14A** to **14**C are block diagrams showing a modification of the second embodiment of the invention.

[0068] **FIG. 15** is a block diagram showing an example of the configuration of a conventional optical cross connect apparatus (optical transmitting apparatus).

[0069] **FIGS. 16A** to **16**C are diagrams for explaining problems of the conventional technique.

[0070] **FIG. 17** is a block diagram showing the configuration of the conventional optical cross connect apparatus for explaining the problems of the conventional technique.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A. First Embodiment

[0071] **FIG. 1** is a block diagram showing the configuration of an optical cross connect apparatus (optical transmitting apparatus) of a first embodiment of the invention. An optical cross connect apparatus (hereinbelow, also called a node) **1** shown in **FIG. 1** is an apparatus to which wavelength division multiplex signal lights (WDM lights) of maximum N wavelengths (λ1 to λN, where N denotes an integer of 2 or larger) are input from K pieces (K: an integer of 2 or larger) of transmission paths (input light transmission paths) #**1** to #K and which can output WDM lights of maximum N wavelengths to each of K pieces of transmission paths (output light transmission paths) #**1** to #K. When the number of add signal light wavelengths to be output (added) to any of the output light transmission paths #**1** to #K are m (=I_add), the number of drop signal light wavelengths to be dropped from any of the input light transmission paths #**1** to #K are n (=I drop), the minimum integer of integers M satisfying the relation of M≧I_add/N is M_add, and the minimum integer of integers M' satisfying the relation of M'≧I_drop/N is M_drop, the optical cross connect apparatus **1** is constructed by the following components.

[0072] The optical cross connect apparatus **1** is constructed by: K pieces of 1×P wavelength selection switches (WSS) **11-1** to **11**-K each having one input port and output ports of the number which is P at the minimum (P=K+M_drop−1) provided for the transmission paths (input transmission paths) #**1** to #K; K pieces of (Q-input 1-output) multiplexers **12-1** to **12**-K each having minimum Q (=K+M_add−1) input ports and one output port provided for K pieces of output optical transmission paths #**1** to #K; M_add pieces of (m-input 1-output) multiplexers **13** for optical transmitters **2-1** to **2-*m*** of the number corresponding to the number of insertion (add) signal light wavelengths m (=1_add); M_add pieces of (1×K) wavelength selection switches **14** provided on the output side of the multiplexers **13** and each having one input port and K output ports (output ports #**1** to #K); M_drop pieces of (K-input 1-output) multiplexers **15** for the optical receivers **3-1** to **3-*n*** of the number corresponding to the number of drop signal light wavelengths n (=1_drop); and M_drop pieces of wavelength selectors **16** which are provided on the output side of the multiplexers **15**, whose outputs are connected to the optical receivers **3-1** to **3-*n***, and each having one input port and n output ports.

[0073] **FIG. 1** shows the case where the number of add signal wavelengths m (=I_add)≧wavelength multiplexing number N and the number of drop signal light wavelengths n (=I_drop)≧wavelength multiplexing number N, that is, M_add=M_drop=1 and P=Q=K. In the following, description will be given on the preconditions.

[0074] Each 1×K wavelength selection switch (optical path switching means) **11-*i*** (where i=**1** to K) (hereinbelow, simply described as a 1×K wavelength selection switch **11** in the case where the switches are not distinguished from each other) can selectively output signal light having one or more arbitrary wavelengths from signal lights having wavelengths λ1 to λN constructing WDM signal light input from the transmission path #i to any of the output ports #**1** to #K. Each of the output ports #**1** to #K is connected to one of input ports of the K−1 pieces of multiplexers **12-1** to **12**-K corresponding to different paths (including the paths to the optical receivers **3-1** to **3-*n***) except for the same transmission path #i and input ports of the multiplexer **15** provided for the optical receivers **3-1** to **3-*n*** via an optical fiber (fiber patch cord). For example, when attention is paid to the 1×K wavelength selection switch **11-1** positioned in the highest stage in **FIG. 1**, the output ports #**1** to #K−1 are connected to the input ports #**1** of the different multiplexers **12-2** to **12**-K except for the multiplexer **12-1** corresponding to the same path #**1**, and the remaining one output port #K is connected to the input port #**1** of the multiplexer **15**. The other switches are connected similarly.

[0075] Concretely, for example, as shown in **FIGS. 2 and 3**, the wavelength selection switch **11-*i*** is constructed by a space optical switch including a circulator **111**, an input collimator **112-1**, an output collimator **112-2**, dispersing parts **113-1** and **113-2**, and an MEMS (Micro Electro Mechanical Systems) mirror unit **114** on which tilt mirrors **115** of the number corresponding to the maximum wavelength number N included in the input WDM light. The WDM light input to the input-side dispersing part **113-1** via the circulator **111** is dispersed on the wavelength unit basis, the dispersed light is emitted to the different tilt mirrors **115** (**115*a*** and **115*b***), the tilt angle (mirror angle) of the tilt mirror **115** is controlled every wavelength to change the reflecting direction of incident light (optical path), thereby enabling the destination (output port) to be selected every wavelength.

[0076] For example, in the case where K=2, specifically, in the case of the 1×2 wavelength selection switch **11-*i*** and the wavelength multiplexing number N=2, the WDM light incident from an input port enters from the circulator **111** to the input collimator **112-1** and is converted to collimate light by the input collimator **112-1**, the collimate light is incident on the dispersing part **113-1**, dispersed to signal lights having wavelengths λ1 and λ2 by the dispersing part **113-1**, and the signal lights are incident on the different tilt mirrors **115*a*** and **115*b***. When the mirror angles of the tilt mirrors **115*a*** and **115*b*** are controlled so that the signal lights are incident on the dispersing part **113-2**, as shown by broken lines (the optical path of the wavelength λ1) and solid lines (the optical path of the wavelength λ2) in **FIG. 2**, the signal lights having the wavelengths λ1 and λ2 are output (reflected) by the tilt mirrors **115*a*** and **115*b*** to the dispersing part **113-2** on the output side and multiplexed by the multiplexer **113-2**, and the resultant is output from the output port #**2** via the output collimator **112-2**.

[0077] On the other hand, for example, as shown in **FIG. 3**, the mirror angle of the tilt mirror **115*a*** corresponding to the wavelength λ2 is controlled so that the signal light having the wavelength λ2 returns to the input-side dispersing part **113-1**, and the mirror angle of the tilt mirror **115*b*** is set so as to make the signal light having the wavelength λ1 go out to the output-side dispersing part **113-2** in a manner similar to the case of **FIG. 2**. The signal light having the wavelength λ2 enters the dispersing part **113-1**, input collimator **112-1**, and circulator **111** in order and goes out from the output port #**1**. The signal light having the wave-

length λ2 enters the dispersing part **113-1** and the output collimator **112-2** in order and goes out from the output port #**2**.

[**0078**] By the principle as described above, the wavelength selection switch **11**-*i* of the embodiment can selectively output signal light having one or more arbitrary wavelengths included in input WDM light to any of the output ports #**1** to #K.

[**0079**] In **FIG. 1**, each multiplexer **12**-i (hereinbelow, simply expressed as multiplexer **12** when the multiplexers are not distinguished from each other) multiplexes signal lights having different wavelengths which are input from the different wavelength selection switches **11**-*i* and **14** except for the wavelength selection switch **11**-*i* corresponding to the same transmission path #i, that is, which are input from different paths (including paths from the optical transmitters **2-1** to **2**-*m*) and outputs the multiplexed signal light to the transmission path #i.

[**0080**] Further, the multiplexer **13** multiplexes add signal lights input from the optical transmitters **2-1** to **2**-*m* (hereinbelow, simply expressed as optical transmitter **2** when the optical transmitters are not distinguished from each other) and outputs the resultant to the 1×K wavelength selection switch **14**. The 1×K wavelength selection switch **14** selectively outputs signal lights having one or more arbitrary wavelengths from the add signal lights (WDM lights) input from the multiplexer **13** to the output ports #**1** to #K. As shown in **FIG. 1**, each the output ports #**1** to #K is connected to one (input port #K) of the input ports of the multiplexers **12**-*i* corresponding to the different transmission paths #I via a fiber patch cord. The optical transmitters **2** and the multiplexer **13** construct an add part **6** as shown in **FIG. 1**.

[**0081**] Each of the input ports #**1** to #K of the multiplexer (drop means) **15** is connected to the output port (#K) as one of the output ports #**1** to #K of each of the 1×K wavelength selection switches **11**-*i* corresponding to the different transmission paths #i via a fiber patch cord, and the multiplexer **15** multiplexes signal lights (drop signal lights) input from the different 1×K wavelength selection switches **11**-*i*, that is, from different transmission paths #i.

[**0082**] The wavelength selector **16** selectively outputs, as drop signal light, signal light having an arbitrary wavelength in WDM light input from the multiplexer **15** to any of the output ports, which is received by any of the optical receivers **3-1** to **3**-*n* (hereinbelow, simply expressed as optical receiver **3** when they are not distinguished from each other). The optical receivers **3** and the wavelength selector **16** construct a drop part **7** as shown in **FIG. 1**. For example, as shown in **FIG. 4**, the wavelength selector **16** can be realized by dropping the power of the input WDM light by an optical coupler **161** and passing only signal light having a wavelength to be received by corresponding one of the optical receivers **3-1** to **3**-*n* via a wavelength variable optical filter **162** provided for each of the optical receivers **3-1** to **3**-*n*.

[**0083**] That is, by providing the 1×K wavelength selection switch **11** having one input port and having K output ports for each of K pieces of the input transmission paths #**1** to #K, providing one multiplexer **12** having K input ports and one output port for each of the output transmission paths #**1** to #K, and connecting (K−1) pieces of the multiplexers **12** except for one multiplexer **12** having the same path as that of one 1×K wavelength selection switch **11**, the optical cross connect function (optical cross connect means) capable of outputting all of input signal lights to all of the output transmission paths #**1** to #K except for the same path is realized.

[**0084**] For the add signal lights #**1** to #m, the multiplexer **13** for multiplexing the add signal lights #**1** to #m and the 1×K wavelength selection switch **14** are provided and an output of the switch **14** is connected to the multiplexers **12** provided for the output transmission paths #**1** to #K, thereby realizing an add function (add wavelength output means) capable of outputting add signal lights from all of the optical transmitters **2** to arbitrary output transmission paths #**1** to #K. By providing the multiplexer **15** having K input ports in correspondence with the output ports which are not connected to the multiplexers **12** provided for the output transmission paths #**1** to #K out of the output ports of the 1×K wavelength selection switches **12** provided for the input transmission paths #**1** to #K and the wavelength selector **16** for dropping a drop wavelength, a drop function (drop wavelength output means) capable of receiving signal lights (drop signal lights #**1** to #n) having arbitrary wavelengths input from arbitrary one of the input transmission paths #**1** to #K by an arbitrary optical receiver **3** is realized.

[**0085**] With the above-mentioned configuration, in the optical cross connect apparatus **1** of the embodiment shown in **FIG. 1**, the transmission path of WDM signal light having N wavelengths at the maximum to be input/output from/to K pieces of transmission paths #**1** to #K is switched on the wavelength unit basis, the add signal lights #**1** to #m having the m wavelengths at the maximum from the optical transmitters **2-1** to **2**-*m* can be added to an arbitrary transmission path #i, and the signal lights #**1** to #n having the n wavelengths at the maximum can be dropped from the WDM light on an arbitrary transmission path #i and received by the arbitrary optical receivers **3-1** to **3**-*n*.

[**0086**] Now, for example, as shown in **FIG. 5**, the case will be examined where transmission path number K=2, wavelength multiplexing number N=80, the number of add signal light wavelength m=80, and the number of drop signal light wavelength n=80 (that is, M_add=M_drop=1, P=Q=K=2), that is, the case where, in the optical cross connect apparatus **1** which inputs/outputs WDM light having 80 wavelengths from/to each of the two transmission paths A and B and capable of dropping/adding signal lights having 80 wavelengths, wavelengths λ1 to λ80 are dropped from signal lights having the wavelength λ1 to λ80 input from the transmission path A, the path of wavelengths λ21 to λ80 is changed to the transmission path B, wavelengths λ'1 to λ'20 of add signal light are output to the transmission path B, and wavelengths λ'21 to λ'80 are output to the transmission path A.

[**0087**] In this case, the signal lights having the wavelengths λ1 to λ20 in the WDM light input from the path A to the 1×2 wavelength selection switch **11-1** is output from an output port a1 connected to the multiplexer **12-2** corresponding to the transmission path B, and the remaining wavelengths λ21 to λ80 are output as drop signal light from the other output port a**2**. The drop signal light output from the output port a**2** is multiplexed on other drop signal light from the 1×2 wavelength selection switch **11-2** corresponding to the transmission path B in the multiplexer **15**, and the

wavelength is selected and output by the wavelength selector **16** and received by desired one of the optical receivers **3-1** to **3-80**.

[**0088**] On the other hand, signal light output from the output port a**1** of the 1×2 wavelength selection switch **11-1** is output to the transmission path B via the multiplexer **12-2**. Add signal lights (λ'1 to λ'80) are multiplexed by the multiplexer **13**, the resultant is input to the 1×2 wavelength selection switch **14** where the signal lights having the wavelengths λ'1 to λ'20 are output from the output port b**2** connected to the multiplexer **12-2** corresponding to the transmission path B, and the signal lights having the wavelengths λ'21 to λ'80 are output from the output port b**1** connected to the multiplexer **12-1** corresponding to the transmission path A. In such a manner, the signal lights having the wavelengths λ'1 to λ'20 can be output (added) to the transmission path B, and the signal lights having the wavelengths λ'21 to λ'80 can be output (added) to the transmission path A.

[**0089**] As described above, in the optical cross connect apparatus **1** of the embodiment, to realize the optical cross connect function capable of outputting signal lights from arbitrary one of the input transmission paths #**1** to #K to arbitrary one of the output transmission paths #**1** to #K, it is sufficient to provide K pieces of wavelength selection switches **11** and K pieces of multiplexers **12** for K pieces of transmission paths. In addition, to realize an add function capable of outputting (adding) an arbitrary add signal light to arbitrary one of the output transmission paths #**1** to #K, it is sufficient to provide M_add (=**1**) piece each of the multiplexer **13** and the wavelength selection switch **14**. Further, to realize a drop function enabling signal light of arbitrary one of the input transmission paths #**1** to #K to be received by an arbitrary optical receiver **3**, it is sufficient to provide M_drop (=1) piece each of the multiplexer **15** and the wavelength selector **16**. Thus, the number of optical wires (the number of fiber patch cords) necessary in the optical cross connect apparatus can be reduced largely more than that in the conventional apparatus.

[**0090**] For example, in the configuration of **FIG. 1**, when the transmission path number K=4, wavelength multiplexing number N=80, and the number of add/drop signal light wavelengths m=n=10 (that is, M_add=M_drop=1, P=Q=K=4), the configuration of the optical cross connect apparatus **1** is as shown in **FIG. 6**. The optical cross connect apparatus **1** shown in **FIG. 6** is an apparatus having functions equivalent to those of the optical cross connect apparatus **100** using a matrix switch described as the prior art by referring to **FIGS. 12 and 14**. In the configuration of the embodiment shown in **FIG. 6**, the number of optical fiber patch cords installed in the node is 42 in total which is only about 6% of the configuration shown in **FIG. 12**.

[**0091**] In the configurations shown in **FIGS. 1 and 5**, the number of the input port (optical wire) of each multiplexer **12** or the output port (optical wire) of each wavelength selection switch **11** occupied for add signal light or drop signal light is one irrespective of the wavelength multiplexing number N of the WDM light. Consequently, even when the wavelength multiplexing number N increases, it is unnecessary to change the number of ports necessary for the multiplexer **12**. Optical devices having necessary port number at the technical level of the present circumstances can be sufficiently realized. Moreover, the embodiment largely contributes to realization of the optical cross connect apparatus **1**.

[**0092**] Further, in the case where future increase in the number of transmission paths K and the number of drop/add signal light wavelengths is predicted, the number of output ports of the wavelength selection switch **11** and the number of input ports of the multiplexer **12** are set to be larger than K. For example, by setting each of the output ports of the wavelength selection switch **11** and the number of input ports of the multiplexer **12** to (K+K') ports (that is, by preparing K' pieces of spare ports), it is possible to increase the number of transmission paths by K' pieces or increase the drop/add signal lights by N×K' pieces or more. In short, future expansion of functions of the apparatus can be addressed by the number of spare ports overwhelmingly smaller than that of the conventional configuration.

[**0093**] For example, when it is expected that one transmission path is increased in the future, in the conventional configuration shown in **FIG. 15**, 160 input/output ports are necessary as spare ports. In contrast, in the configuration shown in **FIG. 6**, it is sufficient to provide nine spare ports for each of the output ports of the wavelength selection switch **11** and the input ports of the multiplexer **12**. Also with respect to the apparatus expansibility for increase in the number of transmission paths, the optical cross connect apparatus of the embodiment is overwhelmingly advantageous more than the conventional technique.

(A1) Description of First Modification

[**0094**] **FIG. 7** is a block diagram showing a first modification of the optical cross connect apparatus. An optical cross connect apparatus **1**A shown in **FIG. 7** has a configuration suitable for the case where each of the number of drop/add signal light wavelengths m and n exceeds **80**. The configuration relates to the case where the transmission path number K=2, wavelength multiplexing number N=80, the number of add signal light wavelength m=160, and the number of drop signal light wavelength n=160. In other words, the configuration relates to the case where M_add=M_drop=2 and P=Q=3. As shown in **FIG. 7**, for two input transmission paths A and B (K=2), two 1×3 wavelength selection switches **11'-1** and **11'-2** (K=2) each having one input port and three output ports (P=3) are provided. For two output transmission ports A and B (K=2), two multiplexers **12'-1** and **12'-2** (K=2) each having three input ports (Q=3) and one output port are provided.

[**0095**] For example, for optical transmitters **2-1** to **2-80** (optical transmitter group A) which are the half of optical transmitters **2-1** to **2-160** of 160 wavelengths, a set of a multiplexer **13-1** having 80 input ports and one output port and a 1×K (=2) wavelength selection switch **14-1** is provided. For the remaining optical transmitters **2-81** to **2-160** (optical transmitter group B), similarly, a multiplexer **13-2** having 80 input ports and one output port and a 1×K (=2) wavelength selection switch **14-2** are provided. That is, for the optical transmitters **2-1** to **2-160** of 160 wavelengths, two (M_add=2) multiplexers **13-1** and **13-2** and two 1×K (=2) wavelength selection switches **14-1** and **14-2** are provided.

[**0096**] Similarly, for optical receivers **3-1** to **3-80** (optical receiver group A) which are the half of optical receivers **3-1** to **3-160** of 160 wavelengths, a set of a multiplexer **15-1**

having K input ports and one output port and a wavelength selector **16-1** having one input port and 80 output ports is provided. For the remaining optical receivers **3-81** to **3-160** (optical receiver group B), similarly, a multiplexer **15-2** having K input ports and one output port and a wavelength selector **16-2** having one input port and 80 output ports are provided. That is, for the optical receivers **3-1** to **3-160** of **160** wavelengths, two (M_drop=**2**) multiplexers **15-1** and **15-2** and two wavelength selectors **16-1** and **16-2** are provided.

[**0097**] Each of output ports of one 1×3 wavelength selection switch **11'-1** or **11'-2** is connected to one of input ports of the multiplexers **12'-1**, **12'-2**, **15-1**, and **15-2** corresponding to different transmission paths (including paths to the optical receiver groups A and B) except for the same transmission path A or B via an optical link. Each of output ports of one 1×2 wavelength selection switch **14-1** or **14-2** for add signal light is connected to one of input ports of the multiplexers **12'-1** and **12'-2** corresponding to the different transmission paths A and B.

[**0098**] Also in the modification, the 1×3 wavelength selection switch **11'-1** (**11'-2**) can selectively output signal light having one or more arbitrary wavelengths out of 80 wavelengths constructing WDM light input from the input transmission path A (B) to any of the three output ports **c1**, **c2**, and **c3**. The multiplexer **13-1** multiplexes add signal lights from the optical transmitters **2-1** to **2-80** constructing the optical transmitter group A, and the 1×2 wavelength selection switch **14-1** can selectively output light having one or more arbitrary wavelengths out of output light of the multiplexer **13-1** to any of output ports **d1** and **d2**.

[**0099**] The multiplexer **13-2** multiplexes add signal lights from optical transmitters **2-81** to **2-160** constructing the optical transmitter group B. The 1×2 wavelength selection switch **14-2** can selectively output light having one or more arbitrary wavelengths out of output light of the multiplexer **13-2** to any of output ports.

[**0100**] The multiplexer **12'-1** is connected to one of three output ports of each of the 1×3 wavelength selection switches **11'-2**, **14-1**, and **14-2**, multiplexes output lights (that is, signal lights from different paths except for the same transmission path A) of the wavelength selection switches **11'-2**, **14-1**, and **14-2**, and transmits the resultant to the output transmission path A. The multiplexer **12'-2** is connected to one of three output ports of each of the 1×3 wavelength selection switches **11'-*i***, **14-1**, and **14-2**, multiplexes output lights (that is, signal lights from different paths except for the same transmission path B) of the wavelength selection switches **11'-1**, **14-1**, and **14-2**, and transmits the resultant to the output transmission path B.

[**0101**] The multiplexer (dropping means) **15-1** is connected to one of the two output ports of each of the 1×3 wavelength selection switches **11'-1** and **11'-2** corresponding to the input transmission paths A and B and multiplexes output lights (that is, signal lights from different paths A and B) of the wavelength selection switches **11'-1** and **11'-2**. The wavelength selector **16-1** selectively outputs signal light having an arbitrary wavelength from the output light of the multiplexer **15-1** to any of the optical receivers **3-1** to **3-80** constructing the optical receiver group A.

[**0102**] The other multiplexer (dropping means) **15-2** is connected to the other one of the two output ports of each of the 1×3 wavelength selection switches **11'-1** and **11'-2** and multiplexes output lights (that is, signal lights from different paths A and B) of the wavelength selection switches **11'-1** and **11'-2**. The wavelength selector **16-2** selectively outputs signal light having an arbitrary wavelength from the output light of the multiplexer **15-2** to any of the optical receivers **3-81** to **3-160** constructing the optical receiver group B.

[**0103**] With the above-mentioned configuration, the optical cross connect apparatus **1**A capable of inputting/outputting WDM light having 80 wavelengths from/to each of the two transmission paths A and B and dropping/adding signal lights having 160 wavelengths is realized. Specifically, in the configuration shown in **FIG. 6**, by increasing each of the number of output ports of the wavelength selection switches **11'-1** and **11'-2** provided for the input transmission paths A and B and the number of input ports of the multiplexers **12'-1** and **12'-2** provided for the output transmission paths A and B only by one (2 K−1=3), providing two each of the multiplexers **13-1** and **13-2** and the 1×2 wavelength selection switches **14-1** and **14-2** as the multiplexers and 1×2 wavelength selection switches provided for drop signal light, and providing two each of the multiplexers **15-1** and **15-2** and wavelength selectors **16-1** and **16-2** as multiplexers and wavelength selectors for add signal light, the optical cross connect apparatus **1**A in which the number of drop/add wavelengths is **160** at the maximum is realized.

[**0104**] The flow of signal light and add/drop signal light according to a path change in the optical cross connect apparatus **1**A is similar to that in the case shown in **FIG. 5**. Specifically, for example, in **FIG. 7**, when signal lights having the wavelengths λ1 to λ20 out of signal lights having 80 wavelengths λ1 to λ80 input from the input transmission path A are received by any of the optical receivers **3-1** to **3-80** constructing the optical receiver group A, signal lights having wavelengths λ21 to λ40 are received by any of the optical receivers **3-81** to **3-160** constructing the receiver group B, and the transmission path of the signal lights having wavelengths λ41 to λ80 is changed to the transmission path B, each of the signal lights having the wavelengths λ1 to λ20 input from the input transmission path A is output from the output port **c2** of the 1×3 wavelength selection switch **11'-1**, each of the signal lights having the wavelengths λ21 to λ40 is output from the output port **c3** of the 1×3 wavelength selection switch **11'-*i***, and each of the signal lights having the wavelengths λ41 to λ80 is output from the output port cl of the 1×3 wavelength selection switch **11'-1**.

[**0105**] Consequently, each of the signal lights having the wavelengths λ1 to λ20 input from the input transmission path A is dropped and received by any of the optical receivers **3-1** to **3-80** constructing the optical receiver group A via the multiplexer **15-1** and the wavelength selector **16-1**, each of the signal lights having the wavelengths λ21 to λ40 is dropped and received by any of the optical receivers **3-81** to **3-160** constructing the optical receiver group B via the multiplexer **15-2** and the wavelength selector **16-2**, and each of the signal lights having the wavelengths λ41 to λ80 is output to the output transmission path B via the multiplexer **12'-2**.

[**0106**] In the case of outputting add signal lights having wavelengths λ'1 to λ'20 from the optical transmitter group A to the transmission path B and outputting the remaining add signal lights having the wavelengths λ'21 to λ'80 to the

transmission path A, in a manner similar to the configuration shown in **FIG. 5**, the add signal lights having the wavelengths λ'1 to λ'20 are transmitted from the output port d**2** of the 1×2 wavelength selection switch **14-1** and the remaining add signal lights having the wavelengths λ'21 to λ'80 are transmitted from the output port d**1**.

[**0107**] Consequently, the add signal lights having the wavelengths λ'1 to λ'20 are output to the output transmission path B via the multiplexer **12'-2**, and the add signal lights having the wavelengths λ'21 to λ'80 are output to the output transmission path A via the multiplexer **12'-1**. With respect to addition of add signal lights from the optical transmitter group B, similarly, by selectively outputting each of add signal lights to any of the output ports in the 1×2 wavelength selection switch **14-2** in accordance with a target output transmission path A or B, an add signal light having an arbitrary wavelength can be transmitted to an arbitrary transmission path A or B.

(A2) Description of Second Modification

[**0108**] **FIG. 8** is a block diagram showing a second modification of the optical cross connect apparatus described above by referring to **FIGS. 1 and 5**. In a manner similar to the foregoing first modification, an optical cross connect apparatus **1**B shown in **FIG. 8** has a configuration suitable for the case where the number of the drop/add signal light wavelengths exceeds **80**. The configuration relates to the case where the transmission path number K=2, wavelength multiplexing number N=80, the number of add signal light wavelength m=160, and the number of drop signal light wavelength n=160 (that is, M_add=M_drop=2). Also in the second modification, in a manner similar to the first modification, the optical transmitters **2-1** to **2-80** out of the optical transmitters **2-1** to **2-160** for **160** wavelengths construct the optical transmitter group A, and the remaining optical transmitters **2-81** to **2-160** construct the optical transmitter group B. The optical receivers **3-1** to **3-80** out of the optical receivers **3-1** to **3-160** for 160 wavelengths construct the optical receiver group A, and the remaining optical receivers **3-81** to **3-160** construct the optical receiver group B.

[**0109**] The optical cross connect apparatus **1**B shown in **FIG. 8** has K pieces of 1×K wavelength selection switches **11-1** and **11-2** provided for K pieces of output light transmission paths #A and #B for selectively outputting signal lights having one or more arbitrary wavelengths in the input WDM light from any of the minimum K output ports, and K pieces of (K-input 1-output) multiplexers **12-1** and **12-2** provided for K pieces of output light transmission paths #A and #B and each having K pieces of input ports at the minimum and one output port. By connecting one of input ports of (K−1) pieces of the multiplexers **12-1** and **12-1** provided for (K−1) pieces of output optical transmission paths #B and #A different from the input optical transmission paths #A and #B for which the 1×K wavelength selection switches **11-1** and **11-2** are provided to one of the 1×K wavelength selection switches **11-1** and **11-2**, the optical cross connect function (optical cross connect means) capable of outputting all of input signal lights to all of output transmission paths #A and #B except for the same path is realized.

[**0110**] For the optical transmitter group A (the optical transmitters **2-1** to **2-80**), the multiplexer **13-1** having N input ports and one output port, the 1×K (=2) wavelength selection switch **14-1**, and a multiplexer **17-1** having M_add (=2) inputs and one output are provided. For the optical transmitter group B (the optical transmitters **2-81** to **2-160**), the N-input 1-output multiplexer **13-2**, the 1×K (=2) wavelength selection switch **14-2**, and a multiplexer **17-2** having M_add (=2) inputs and one output are provided. For the optical receiver group A (the optical receivers **3-1** to **3-80**), a 1×M_drop (=2) wavelength selection switch **18-1**, the multiplexer **15-1** having K (=2) input ports and one output port, and the wavelength selector **16-1** are provided. For the optical receiver group B (the optical receivers **3-81** to **3-160**), a 1×M_drop (=2) wavelength selection switch **18-2**, the multiplexer **15-2** having K (=2) input ports and one output port, and the wavelength selector **16-2** are provided.

[**0111**] The multiplexer (add wavelength multiplexer) **13-1** having N (=80) input ports and one output port multiplexes add signal lights from the optical transmitter group A (optical transmitters **2-1** to **2-80**), and the 1×2 wavelength selection switch **14-1** can selectively output add signal lights having one or more arbitrary wavelengths out of output light of the multiplexer **13-1** from any of output ports.

[**0112**] The multiplexer (add wavelength multiplexer) **13-2** having N (=80) input ports and one output port multiplexes add signal lights from the optical transmitter group B (optical transmitters **2-81** to **2-160**), and the 1×2 wavelength selection switch **14-2** can selectively output add signal lights having one or more arbitrary wavelengths out of output light of the multiplexer **13-2** from any of output ports.

[**0113**] Each of the multiplexers **17-1** and **17-2** each having M_add (=2) input ports and one output port is connected to one of three output ports of each of the 1×K (=2) wavelength selection switches **14-1** and **14-2** and multiplexes output lights of the wavelength selection switches **14-1** and **14-2**. The output of the multiplexer **17-1** is connected to one of the input ports of the multiplexer **12-1**, and the output of the multiplexer **17-2** is connected to one of the input ports of the multiplexer **12-2**.

[**0114**] The set of the multiplexer **13-1** and the wavelength selection switch **14-1** and the set of the multiplexer **13-2** and the wavelength selection switch **14-2** function as M_add (=2) pieces of add wavelength multiplexing and selecting units each having minimum K pieces of output ports, multiplexing add signal lights having N (=80) wavelengths at the maximum from the optical transmitters **2-1** to **2-80**, and selectively outputting add signal lights having one or more arbitrary wavelengths from the output ports. One of the input ports of each of the multiplexers **17-1** and **17-2** each having M_add (=2) input ports and one output port is connected to one of the output ports of each of the M_add (=2) pieces of the add wavelength multiplexing and selecting units. The output port of the multiplexer **17-1** having M_add (=2) input ports and one output port is connected to one of the input ports of the multiplexer **12-1** having K (=2) input ports and one output port, and the output port of the multiplexer **17-2** having M_add (=2) input ports and one output port is connected to one of the input ports of the multiplexer **12-2** having K (=2) input ports and one output port. With the configuration, an adding function (add wavelength output means) capable of outputting add signal lights from arbitrary optical transmitters **2-1** to **2-16** in the optical transmitter groups A and B to an arbitrary transmission path #i (A or B) is realized.

[0115] The 1×M_drop (=2) wavelength selection switch (drop light switching means) **18-1** has the input port connected to one of the output ports of the 1×K (=2) wavelength selection switch **11-1** provided for the input transmission path A, and can selectively output signal lights having one or more arbitrary wavelengths in the signal lights from the input transmission path A input via the input port to one of the K (=2) pieces of multiplexers **15-1** and **15-2**. The 1×M_drop (=2) wavelength selection switch (drop light switching means) **18-2** has the input port connected to one of the output ports of the 1×K (=2) wavelength selection switch **11-2** provided for the input transmission path B, and can selectively output signal lights having one or more arbitrary wavelengths in the signal lights from the input transmission path B input via the input port to one of the K (=2) pieces of multiplexers **15-1** and **15-2**.

[0116] One of the K (=2) pieces of input ports of the multiplexer (drop wavelength multiplexer) **15-1** is connected to one of output ports of the 1×M_drop (=2) wavelength selection switch **18-1** and the other input port is connected to one of output ports of the 1×M_drop (=2) wavelength selection switch **18-2**. The multiplexer **15-1** multiplexes signal lights from the K(=2) pieces of wavelength selection switches **18-1** and **18-2**. One of the K (=2) pieces of input ports of the multiplexer (drop wavelength multiplexer) **15-2** is connected to the remaining (other) output port of the 1×M_drop (=2) wavelength selection switch **18-1**, and the other input port is connected to the remaining (other) output port of the 1×M_drop (=2) wavelength selection switch **18-2**. The multiplexer **15-2** multiplexes signal lights from the K(=2) pieces of wavelength selection switches **18-1** and **18-2**.

[0117] The wavelength selector **16-1** selectively outputs signal light having an arbitrary wavelength from the output light of the corresponding multiplexer **15-1** to any of the optical receivers **3-1** to **3-80** constructing the optical receiver group A so as to be received. The wavelength selector **16-2** selectively outputs signal light having an arbitrary wavelength from the output light of the corresponding multiplexer **15-2** to any of the optical receivers **3-81** to **3-160** constructing the optical receiver group B so as to be received.

[0118] Each of the set of the multiplexer **15-1** and the wavelength selector **16-1** and the set of the multiplexer **15-2** and the wavelength selector **16-2** is connected to one of the output ports of each of the K (=2) pieces of 1×M_drop (=2)wavelength selection switches **18-1** and **18-2**. The sets function as K pieces of drop wavelength multiplexing and selecting units, each multiplexing outputs of each of the K(=2) pieces of 1×M_drop (=2) wavelength selection switches **18-1** and **18-2** and selectively outputting drop signal light having arbitrary wavelengths. The input port of the wavelength selection switch **18-1** is connected to one of the output ports of the 1×K (=2) wavelength selection switch **11-1**, and the input port of the wavelength selection switch **18-2** is connected to one of the output ports of the 1×K (=2) wavelength selection switch **11-2**. With the configuration, a drop function (drop wavelength output means) capable of selectively dropping signal lights having arbitrary wavelengths from the arbitrary transmission path #i (A or B) so as to be received by any of the optical receivers **3-1** to **3-160** is realized.

[0119] Hereinafter, the operation of the optical cross connect apparatus **1**B constructed as described above will now be described.

[0120] For example, the flow of each signal light will be described below in the case where signal lights having wavelengths λ1 to λ20 in the signal lights having the wavelengths λ1 to λ80 input from the transmission path A are received by any of the optical receivers **3-1** to **3-80** in the optical receiver group A, signal lights having wavelengths λ21 to λ40 are received by any of the optical receivers **3-81** to **3-160** in the optical receiver group B, the path of the signal lights having the wavelengths λ41 to λ80 is changed to the transmission path B, the add signal lights having the wavelengths λ'1 to λ'20 from the optical transmitter group B are output to the transmission path B, and the add signal lights having the remaining wavelengths λ'21 to λ'80 are output to the transmission path A.

[0121] First, each of the signal lights having the wavelengths λ41 to λ80 input from the input transmission path A and to be output to the output transmission path B is output from the output port e**1** of the 1×2 wavelength selection switch **11-1** and input to the multiplexer **12-2** provided for the output transmission path B, thereby enabling the signal lights to be output to the transmission path B.

[0122] On the other hand, the signal lights having the wavelengths λ1 to λ20 input from the input transmission path A and to be received by any of the optical receivers **3-1** to **3-80** of the optical receiver group A and signal lights having the wavelengths λ21 to λ40 to be received by any of the optical receivers **3-81** to **3-160** of the optical receiver group B are output from the output port e**2** of the 1×2 wavelength selection switch **11-1**. The signal lights (drop signal lights) are input to the 1×2 wavelength selection switch **18-1**. By the wavelength selection switch **18-1**, the signal lights having the wavelengths λ1 to λ20 are output to the output port g**1** and the signal lights having the wavelengths λ21 to λ40 are output to the output port g**2**. In such a manner, the drop signal lights are received by an arbitrary one of the optical receivers **3-1** to **3-160** by the multiplexers **15-1** and **15-2** and the wavelength selectors **16-1** and **16-2**.

[0123] The add signal lights from the optical transmitter group A are multiplexed by the multiplexer **13-1**. By the 1×2 wavelength selection switch **14-1**, the signal lights having the wavelengths λ'21 to λ'80 to be output to the output transmission path A are output from the output port f**1**, and the signal lights having the wavelengths λ1 to λ'20 to be output to the output transmission path B are output from the output port f**2**. Since each of the output ports f**1** and f**2** is connected to one of the input ports of the multiplexers **12-1** and **12-2** provided for the output transmission paths A and B via the multiplexers **17-1** and **17-2**, the add signal lights having the wavelengths λ'1 to λ20 can be output to the output transmission path B via the multiplexer **12-2**, and the remaining signal lights having the wavelengths λ'21 to λ'80 can be output to the output transmission path A via the multiplexer **12-1**.

[0124] Also with respect to the add signal lights from the optical transmitter group B, similarly, an add signal light having an arbitrary wavelength can be output to an arbitrary output transmission path A or B via the multiplexer **13-2**, 1×2 wavelength selection switch **14-2**, multiplexers **17-1** and **17-2** and the multiplexers **12-1** and **12-2**.

[0125] As described above, in the optical cross connect apparatus **1**B of the modification, different from the first modification, the number of output ports of the wavelength selection switches **11-1** and **11-2** and the number of input ports of the multiplexers **12-1** and **12-2** provided for the transmission paths A and B can be set to be constant (K) without depending on the number of drop/add signal light wavelengths. Consequently, the number of drop/add signal lights can be increased without exerting an influence on at least the signal lights related to a path change.

[0126] The add signal lights are multiplexed by the multiplexers **13-1** and **13-2**, add signal lights having one or more arbitrary wavelengths are changed by the wavelength selection switches **14-1** and **14-2**, and the add signal lights after the wavelength change are multiplexed by the multiplexers **17-1** and **17-2**. On the other hand, the drop signal lights are also changed by the wavelength selection switches **18-1** and **18-2** and, multiplexed by the multiplexers **15-1** and **15-2**, and the resultant is input to the wavelength selectors **16-1** and **16-2**. Consequently, even if the number of drop/add signal light wavelengths increases, the number of output ports of the wavelength selection switches **11-1** and **11-2** and the number of input ports of the multiplexers **12-1** and **12-2** can be suppressed to the transmission path number K. Therefore, those optical devices having the necessary port number can be realized at the technical level of the present circumstances. Moreover, the modification largely contributes to realization of the optical cross connect apparatus **1**B.

[0127] Although each of the optical cross connect apparatuses **1**, **1**A and **1**B of the foregoing first embodiment has both of the adding function and the dropping function, the invention is not limited to the configuration. Each of the optical cross connect apparatuses **1**, **1**A, and **1**B may have only one of the functions. The configuration of the add part **6** and the drop part **7** can be properly changed according to the configuration of the optical cross connect apparatus (OADM) **1**. Examples of the configuration are (1) passive OADM (POADM), (2) reconfigurable OADM (ROADM), and (3) dynamic OADM (DOADM).

[0128] Each of the POADM, ROADM, and DOADM is constructed (defined) as shown in **FIG. 9**. Specifically, in the POADM, the drop or through wavelength is fixed (not automatically switchable), an arbitrary add signal light wavelength cannot be added to an arbitrary add port, and an arbitrary drop signal light wavelength cannot be dropped to an arbitrary drop port (transponder having a set of the optical transmitter **2** and the optical receiver **3**). The POADM is a node in which reconnection between the OADM and the transponder has to be performed manually.

[0129] In the case of such a POADM node, for example, as shown in **FIG. 10A**, the add part **6** uses the optical transmitters **2** each having the fixed transmission wavelength and an AWG (Array Waveguide Grating) as the multiplexer **13**. In correspondence with the add part **6**, the drop part **7** uses an AWG as the wavelength selector **16** and uses the optical transmitters **3** each having the fixed reception wavelength. In **FIG. 10A**, reference numerals **8** and **9** denote optical amplifiers for compensating an optical loss caused by the AWGs.

[0130] In the ROADM, as shown in the column (**2**) in **FIG. 9**, the drop/through wavelengths can be automatically switched. However, like the POADM, an arbitrary add signal light wavelength cannot be added to an arbitrary add port, and an arbitrary drop signal light wavelength cannot be dropped to an arbitrary drop port (transponder). The ROADM is a node in which reconnection between the OADM and the transponder has to be performed manually.

[0131] In contrast, in the DOADM, as shown in the column (**3**) in **FIG. 9**, the drop/through wavelengths can be automatically switched and, moreover, an arbitrary add signal light wavelength can be added to an arbitrary add port, and an arbitrary drop signal light wavelength can be dropped to an arbitrary drop port (transponder). The DOADM is a node in which reconnection between the OADM and the transponder does not have to be performed manually. In the case of the DOADM node, for example, as shown in **FIG. 10B**, each of the add part **6** and the drop part **7** can be constructed in three modes.

[0132] Specifically, as shown in **FIG. 10B**, the add part **6** uses the optical transmitters **2** whose transmission wavelength is variable and the multiplexer **13** which can be constructed by (1) an N×1 wavelength selection switch (WSS), (2) an N×1 coupler, or (3) combination of an N×N matrix switch **13***a* and an AWG **13***b*. In correspondence with the configuration, the drop part **7** uses the optical receiver **3** whose reception wavelength is variable and the wavelength selector **16** which can be constructed by (1) a 1×N wavelength selection switch (WSS), (2) an N×1 coupler, or (3) combination of an AWG **16***b* and an N×N matrix switch **16***a*.

[0133] The configurations which can be employed for the add part **6** and the drop part **7** are also similarly applied to the following embodiments.

B. Description of Second Embodiment

[0134] **FIGS. 11A** to **11**C are diagrams showing images of an optical node in-service upgrading method (path adding method) according to a second embodiment of the invention. For example, as shown in **FIG. 1A**, in the case of upgrading an ROADM node (optical transmitting apparatus) **1**C of 2 degrees to an optical cross connect (WXC) node of 3 degrees during service operation, as shown in **FIG. 11B**, by connecting a modular switch (optical switch module) **5-1** to an idle (unused) port for upgrading which is prepared in advance for the ROADM node **1**C, the number of paths (transmission paths) is increased. In the case of also preliminarily providing the modular switch **5-1** with an idle (unused) port for upgrading and further increasing the number of paths to construct a WXC node having 4 degrees from the node having 3 degrees, as shown in **FIG. 11C**, by connecting a modular switch **5-2** having an idle port for upgrading to the idle port of the modular switch **5-1**, the number (K) of paths (transmission paths) is increased. Also in **FIGS. 11A** to **11**C, the wavelength multiplexing number N per degree is set to 80 wavelengths. Reference numeral **2** denotes an optical transmitter for add signal light, **3** denotes an optical receiver for drop signal light, and **4** indicates an optical amplifier such as an EDFA (Erbium Doped Fiber Amplifier).

[0135] As described above, at the time of initial installation, the node **1**C is provided with an idle port for upgrading. In the case of increasing the number of degrees, by sequentially connecting the modular switches **5-1**, **5-2**, . . . for preparing an idle port for upgrading (hereinbelow, also simply expressed as modular switch **5** when they are not

distinguished from each other), the cost may be the minimum at the time of initial installation of the node **1**C and the number of degrees can be arbitrarily increased later. With respect to a signal passing through the increased part, since the signal passes through the modular switches **5** in many stages, to prevent deterioration in the optical signal to noise ratio (OSN), it is necessary to prevent or sufficiently reduce an optical loss.

[**0136**] **FIG. 12** shows a concrete example of the image (modular type upgrading) described with reference to **FIG. 11**. **FIG. 12** is a block diagram showing the configuration where the modular switch **5-1** is connected to the node **1**C. The configuration shown in **FIG. 12** relates to the case where the final number K of degrees=3, and the number of add signal light wavelengths m=the number of drop signal light wavelengths n=80×3 (groups)=240 wavelengths. In **FIG. 12**, devices drawn by solid lines indicate existing portions (before addition) and devices drawn by broken lines indicate added portions.

[**0137**] Specifically, the node **1**C before upgrading has: 1×3 wavelength selection switches **11-1** and **11-2** each having one input port and three output ports for the input transmission paths #**1** and #**2** (signal lights according to a path change); 3×1 wavelength selection switches **21-1** and **21-2** each having three input ports and one output port for the output transmission paths #**1** and #**2**; and two pieces (=the number K of degrees) each of multiplexers (**13-1** and **13-2**) each for multiplexing 80 wavelengths and demultiplexers (**22-1** and **22-2**) each for demultiplexing 80 wavelengths for add/drop signal lights having **160** wavelengths (=80 wavelengths λ1 to λ80×2) (for 160 optical transmitters (Tx) **2** and 160 optical receivers (Rx) **3**). In **FIG. 12**, reference numeral **4** denotes optical amplifiers. **FIG. 12** shows a state where a set of the optical transmitter **2** and the optical receiver **3** is provided for each of transponders (TRP) #**1** to #**80**.

[**0138**] In this case as well, like the configuration shown in **FIG. 1**, one of the three output ports of the 1×3 wavelength selection switch **11-1** provided in correspondence with the input transmission path #**1** is connected to one of the input ports of the 3×1 wavelength selection switch **21-2** provided for the output transmission path #**2** different from the same transmission path #**1**. Another one is connected to the demultiplexer **22-2** provided for the optical receiver group #**1**, and the remaining port is set as an idle (spare) port for upgrading.

[**0139**] Similarly, one of the three output ports of the 1×3 wavelength selection switch **11-2** provided in correspondence with the input transmission path #**2** is connected to one of the input ports of the 3×1 wavelength selection switch **21-1** provided for the output transmission path #**1** different from the same transmission path #**2**. Another one is connected to the input port of the demultiplexer **22-1** provided for the optical receiver group #**2**, and the remaining port is set as an idle port for upgrading.

[**0140**] Consequently, as shown by the paths of solid lines in **FIG. 13**, the path of a signal light having arbitrary wavelengths from an arbitrary input transmission path #**1** or #**2** can be changed to an arbitrary output transmission path #**1** or #**2**, and a signal light having arbitrary wavelengths from an arbitrary input transmission path #**1** or #**2** can be dropped and received by an arbitrary optical receiver **3**.

[**0141**] An output of the multiplexer **13-1** provided for the optical transmitter group (add signal light group) #**1** is connected to one of input ports of the 3×1 wavelength selection switch **21-1** provided for the output transmission path #**1** (the remaining one input port is an idle port), and an output of the multiplexer **13-2** provided for the optical transmitter group (add signal light group) #**2** is connected to one of input ports of the 3×1 wavelength selection switch **21-2** provided for the output transmission path #**2** (the remaining one input port is an idle port). With the configuration, add signal lights having arbitrary wavelengths from the optical transmitter groups #**1** and #**2** can be output to the arbitrary output transmission paths #**1** and #**2**.

[**0142**] In the case of upgrading the 2-degree configuration to a 3-degree configuration, that is, in the case of adding a transmission path #**3** and an add signal light group (optical transmitter group) #**3**, as shown in **FIG. 12**, a modular switch **5** (**5-1**) having 1×4 wavelength selection switches **11-3** and **21-3**, 1×2 wavelength selection switches **19-1** and **19-2**, 2×1 wavelength selection switches **20-1** and **20-2**, a multiplexer **13-2**, and a demultiplexer **22-3** which are fiber-connected in advance as shown in **FIG. 12** is connected to the node **1**C.

[**0143**] Specifically, as shown in **FIGS. 12 and 13**, the 1×4 wavelength selection switch **11-3** and the 4×1 wavelength selection switch **21-3** are provided for the added transmission path #**3**, the wavelength selection switches **19-1** and **19-2** each having one input and k outputs (where k denotes an integer of 2 or larger, in this case k=2) [that is, 1×k (=2)] and the k(=2)-input 1-output (k×1) wavelength selection switches **20-1** and **20-2** are newly provided, the multiplexer **13-3** is provided for the added optical transmitter group #**3**, and the demultiplexer **22-3** is provided for the added optical receiver group #**3**.

[**0144**] The input port of the 1×2 wavelength selection switch **19-1** is connected to the idle port of the existing 1×3 wavelength selection switch **11-1** for the input transmission path #**1**, and one of the two output ports is connected to one of the input ports of the added 4×1 wavelength selection switch **21-3**. The remaining (other) output port of the 1×2 wavelength selection switch **19-1** is set as an idle port for further upgrading.

[**0145**] Similarly, the input port of the 1×2 wavelength selection switch **19-2** is connected to the idle port of the existing 1×3 wavelength selection switch **11-2** for the input transmission path #**2**, and one of the two output ports is connected to another one of the input ports of the added 4×1 wavelength selection switch **21-3**. The remaining (other) output port is set as an idle port for further upgrading.

[**0146**] One of the input ports of the added 2×1 wavelength selection switch **20-1** is connected to one of the output ports of the 1×4 wavelength selection switch **11-3** added to the added input transmission path #**3**, the remaining one is set as the idle port for upgrading, and the output port of the wavelength selection switch **20-1** is connected to the idle port of the existing 3×1 wavelength selection switch **21-1** for the output transmission path #**1**.

[**0147**] Similarly, one of the input ports of the added 2×1 wavelength selection switch **20-2** is connected to another one of the output ports of the 1×4 wavelength selection switch **11-3** added to the added input transmission path #**3**,

the remaining one is set as the idle port for upgrading, and the output port of the wavelength selection switch **20-2** is connected to the idle port of the existing 3×1 wavelength selection switch **21-2** for the output transmission path #**2**.

[**0148**] Further, one of the four output ports of the 1×4 wavelength selection switch **11-3** added to the input transmission path #**3** is connected to one of the input ports of the added 2×1 wavelength selection switch **20-1**, another output port is connected to one of the input ports of the added 2×1 wavelength selection switch **20-2**, another output port is connected to the multiplexer **22-3** added to the optical receiver group #**3**, and the remaining output port is set as the idle port for upgrading.

[**0149**] With respect to four input ports of the 4×1 wavelength selection switch **21-3** added to the output transmission path #**3**, except for the input ports to which one output port of the 1×2 wavelength selection switch **19-1** and one output port of the 1×2 wavelength selection switch **19-2** are connected, one input port is connected to the output port of the multiplexer **22-3** added to the optical transmitter group #**3**, and the remaining one port is set as an idle port for upgrading.

[**0150**] By the connection (optical wiring), a signal light having arbitrary wavelengths can be output from arbitrary one of the input transmission paths #**1**, #**2**, and #**3** to arbitrary one of the output transmission paths #**1**, #**2**, and #**3**, a signal light having arbitrary wavelengths from arbitrary one of the input transmission paths #**1**, #**2**, and #**3** can be dropped and received by an arbitrary optical receiver **3**, and an add signal light having arbitrary wavelengths can be output to arbitrary one of the output transmission paths #**1**, #**2**, and #**3**.

[**0151**] As described above, each of the wavelength selection switches, multiplexers, and demultiplexers (their reference numerals are omitted here) used in the OADM node **1**C is used always in a form that at least one port is set as the unused (idle) port for upgrading. Each time the number of degrees is increased, the minimum wavelength selection switch, multiplexer, and demultiplexer are tandem-connected to an idle port. In such a manner, unlike the conventional technique, without preliminarily predicting a final form and preparing necessary spare optical devices such as wavelength selection switches and an enormous number of spare ports from the initial introduction, increase in the number of degrees (upgrading) can be flexibly dealt with the minimum idle ports. In particular, in the case of the embodiment, as understood from **FIG. 12**, no influence is exerted to transmission of existing signal lights at the time of upgrading, so that service interruption is unnecessary (in other words, in-service upgrading is possible).

[**0152**] For example, the added optical devices (wavelength selection switches, multiplexers, and demultiplexers) and the optical wires between them are constructed as a set of the modular switch **5**. As described above by referring to **FIGS. 11B and 11C**, only by connecting the modular switch **5** to the idle ports prepared in the existing optical devices, the in-service upgrading of the number of degrees can be easily realized and the burden of work at the time of addition can be largely reduced.

[**0153**] To make the quality of a signal passing through the added wavelength selection switches **19-1**, **19-2**, **20-1**, and **20-2** in multiple stages equivalent to the quality before the upgrading, it is preferable to provide a low gain optical amplifier **23** for compensating an optical loss or the like in each of the added wavelength selection switches **19-1**, **19-2**, **20-1**, and **20-2**. With the configuration, an optical loss of signal light passing through a plurality of wavelength selection switches in multiple stages can be properly compensated. Even if the number of transmission paths is increased by adding the modular switch **5**, necessary transmission characteristics of the signal light can be assured. As the characteristics of the optical amplifier **23**, although the gain may be low (about 3 to 5 dB of a loss of the wavelength selection switch), it is desirable to cover the transmission wavelength band and to maintain the same gain even if the input wavelengths change.

[**0154**] Each of the wavelength selection switches **21-1**, **21-2**, and **21-3** positioned in the final output stage may be constructed by using a multiplexer. From the viewpoint of reducing the kinds of devices at the time of constructing the modular switch **5**, it is preferable to use the wavelength selection switch.

(B1) Description of Modification of Second Embodiment

[**0155**] As a modification of the second embodiment, processes for addressing unexpected addition of traffic will be described. For example, as shown in **FIG. 14A**, when sites (communication points) A, B, and C exist, initially, traffic exists only between the sites A and B and between the sites B and C and no traffic exists between the sites A and C, the configuration of the node **1**C is as shown in **FIG. 14B**.

[**0156**] Specifically, the 1×2 wavelength selection switch **11-1**, 1×3 wavelength selection switch **11-2**, and 1×2 wavelength selection switch **11-3** are provided for the input transmission paths (hereinbelow, referred to as the input transmission paths #A, #B, and #C) on the sites A, B, and C, respectively, and the 2×1 wavelength selection switch **21-1**, 3×1 wavelength selection switch **21-2**, and 2×1 wavelength selection switch **21-3** are provided for the output transmission paths (hereinbelow, referred to as the output transmission paths #A, #B, and #C) on the sites A, B, and C, respectively.

[**0157**] For the traffic from the site B to the site A and the traffic from the site B to the site C, one of the output ports of the 1×3 wavelength switch **11-2** for the input transmission path #B is connected to one of the input ports of the 2×1 wavelength selection switch **21-1** for the output transmission path #A, and another output port is connected to one of the input ports of the 3×1 wavelength selection switch **22-2** for the output transmission path #B.

[**0158**] For the traffic from the site A to the site C and the traffic from the site C to the site B, one of the output ports of the 1×2 wavelength switch **11-1** for the input transmission path #A is connected to one of the input ports of the 3×1 wavelength selection switch **22-2** for the output transmission path #B, and one of the output ports of the 1×2 wavelength selection switch **11-3** for the input transmission path #C is connected to one of the input ports of the 2×1 wavelength selection switch **22-2** for the output transmission path #B. The remaining ports are set as idle ports.

[**0159**] As described above, in the communication form shown in **FIG. 14A**, with respect to a route in which sites

exist but there is no traffic in reality, by omitting input/output ports between the site A and the site C of the wavelength selection switch used for the node **1**C, the required number of ports of the wavelength selection switch can be reduced. To be specific, wavelength selection switches except for the wavelength selection switches **11-2** and **21-2** for the input transmission path #B and the output transmission path #B can be set as the 1×2 wavelength selection switches **11-1** and **11-3** and the 2×1 wavelength selection switches **21-1** and **21-3**.

[**0160**] After that, if an unexpected request for traffic between the sites A and C is made as shown by the double-headed arrow with broken line in **FIG. 14A**, by applying the above-described "modular method" and using idle ports for upgrading, traffic between the sites A and C can be added in-service.

[**0161**] Specifically, as shown in **FIG. 14C**, the 1×2 wavelength selection switches **19-1** and **19-2** and the 2×1 wavelength selection switches **20-1** and **20-2** are added, the input port of the 1×2 wavelength selection switch **19-1** is connected to an idle port of the 1×2 wavelength selection switch **11-1** for the input transmission path #A, and the input port of the 1×2 wavelength selection switch **19-2** is connected to an idle port of the 1×2 wavelength selection switch **11-3** for the input transmission path #**3**.

[**0162**] The output port of the 2×1 wavelength selection switch **20-1** is connected to the idle port of the 2×1 wavelength selection switch **21-1** for the output transmission path #A, and the output port of the 2×1 wavelength selection switch **20-2** is connected to an idle port of the 2×1 wavelength selection switch **21-3** for the output transmission path #C. One of the output ports of the 1×2 wavelength selection switch **19-1** is connected to one of the input ports of the 2×1 wavelength selection switch **20-2**, and one of the output ports of the 1×2 wavelength selection switch **19-2** is connected to one of the input ports of the 2×1 wavelength selection switch **20-1**. The remaining ports remain idle ports.

[**0163**] With the configuration, optical links in the direction from the site A to the site C and the direction from the site C to the site A for which a traffic request is newly made are established. In this case, for example, by constructing each of a set of the 1×2 wavelength selection switch **19-1** and the 2×1 wavelength selection switch **20**-land a set of the 1×2 wavelength selection switch **19-2** and the 2×1 wavelength selection switch **20-2** as the modular switch **5**, the work burden at the time of upgrading can be largely reduced.

[**0164**] Obviously, the invention is not limited to the foregoing embodiments but can be variously modified without departing from the gist of the invention.

[**0165**] As described above, according to the invention, while largely reducing the number of wires (optical fiber patch cords) (reducing the size of the apparatus) necessary in an optical transmitting apparatus handling a plurality of transmission paths such as an optical cross connect apparatus and largely reducing the number of spare ports necessary at the time of future addition of a transmission path, the flexible expansion of apparatus function can be realized. Thus, the invention is regarded as extremely useful one in the optical communication technique field.

What is claimed is:

1. An optical transmitting apparatus to which first to K-th (where K denotes an integer of 2 or larger) input transmission paths and first to K-th output transmission paths are connected and which has dropping means, comprising

K pieces of optical path switching means each having an input port connected to said k-th (where k denotes an integer from 1 to K) input transmission path, and K pieces of output ports,

wherein the dropping means has K pieces of input ports connected to said first to K-th optical path switching means, and an output port,

said K pieces of output ports of said optical path switching means whose input port is connected to said k-th input transmission path are connected to said first to K-th output transmission paths except for the k-th output transmission path and to the k-th input port of said dropping means, and

said optical path switching means and said dropping means output light of wavelength which is part or all of wavelength division multiplex light received from said input port from a specific output port, and can output light having a wavelength different from that of the light output from said specific output port from an output port different from said specific output port.

2. An optical transmitting apparatus to which first to K-th (where K denotes an integer of 2 or larger) input transmission paths and first to K-th output transmission paths are connected and which has D pieces (where D denotes a natural number) of dropping means, comprising:

K pieces of optical path switching means each having an input port connected to said k-th (where k denotes an integer from 1 to K) input transmission path, and K pieces of output ports; and

K pieces of drop light switching means each having an input port and D pieces of output ports connected to the first to said D-th dropping means,

wherein said K pieces of output ports of said optical path switching means whose input port is connected to said k-th input transmission path are connected to said first to K-th output transmission paths except for the k-th output transmission path and the input port of said dropping means, and

said optical path switching means and said dropping light switching means output light of wavelength which is part or all of wavelength division multiplex light received from said input port from a specific output port and can output light having wavelength different from that of the light output from said specific output port from an output port different from said specific output port.

3. An optical transmitting apparatus comprising:

optical path switching means having a plurality of input ports connected to a plurality of input optical transmission paths for transmitting wavelength division multiplex signal light and a plurality of output ports connected to a plurality of output optical transmission paths for transmitting wavelength division multiplex signal light, capable of selecting signal light of one or more wavelength included in the wavelength division

multiplex signal light received from any of the input ports and outputting the selected signal light from any of the outports;

add wavelength output means which combines add signal light of a plurality of wavelengths to obtain combined signal light and selectively couples add signal light having one or more wavelengths included in the combined signal light, as signal light to be multiplexed to wavelength division multiplex signal light to any of the output optical transmission paths, to any of the output ports of the optical path switching means; and

drop wavelength output means which selectively receives and combines the signal light having one or more wavelengths included in the wavelength division multiplex signal light input to each of the input ports of the optical path switching means and selectively outputs signal light included in the combined signal light on a wavelength unit basis,

wherein the optical transmitting apparatus is an apparatus to which wavelength division multiplex signal light of the maximum N wavelengths (where N denotes an integer of 2 or larger) is input from each of K pieces (where K denotes an integer of 2 or larger) of input optical transmission paths and which outputs wavelength division multiplex signal light of the maximum N wavelengths to each of the K pieces of output optical transmission paths,

when the minimum integer of integers M satisfying the relation of $M \geqq I_add/N$ where wavelength of add signal light to be output to any of the output optical transmission paths is set as I_add and wavelength of drop signal light to be dropped from any of the input optical transmission paths is set as I_drop is M_add, and the minimum integer of integers M' satisfying the relation of $M' \geqq I_drop/N$ is M_drop,

the optical path switching means comprises K pieces of 1×(K+M_drop−1) wavelength selecting switches provided for the K pieces of input optical transmission paths and selectively outputting signal light of one or more arbitrary wavelengths out of the wavelength division multiplex signal light from any of the (K+M_drop-**1**) output ports at the minimum, and K pieces of (K+M_add−1)-input 1-output multiplexers provided for the K pieces of output optical transmission paths and having (K+M_add-**1**) input ports at the minimum and one output port,

to one of the 1×(K+M_drop−1) wavelength selecting switches, one of the input ports of (K−1) pieces of (K+M_add−1)-input 1-output multiplexers provided for the (K−1) pieces of output optical transmission paths different from the input optical transmission path for which the 1×(K+M_drop−1) wavelength selecting switch is provided is connected,

the add wavelength output means has M_add pieces of add wavelength multiplexing and selecting units each of which is connected to one of the input ports of the K pieces of (K+M_add−1)-input 1-output multiplexers, multiplexes the add signal light of N wavelengths at the maximum, and selectively outputs add signal light of one or more arbitrary wavelengths to any of the K pieces of (K+M_add−1)-input 1-output multiplexers, and

the drop wavelength output means has M_drop pieces of drop wavelength multiplexing and selecting units each of which is connected to one of the output ports of the K pieces of (K+M_drop−1) wavelength selecting switches, multiplexes outputs of the K pieces of 1×(K+M_drop−1) wavelength selecting switches, and selectively outputs drop signal light having arbitrary wavelength.

4. The optical transmitting apparatus according to claim 3, wherein the add wavelength multiplexing and selecting unit comprises:

an add signal light multiplexer for multiplexing the add signal light; and

a 1×K wavelength selecting switch connected to one of the input ports of each of the K pieces of (K+M_add−1)-input 1-output multiplexer and selectively outputting signal light having one or more arbitrary wavelengths included in output light of the add signal light multiplexer to one of the input ports of each of the K pieces of (K+M_add−1)-input 1-output multiplexers.

5. The optical transmitting apparatus according to claim 3, wherein the drop wavelength multiplexing and selecting unit comprises:

a drop signal light multiplexer connected to each of the output ports of the K pieces of 1×(K+M_drop−1) wavelength selecting switches and multiplexing outputs of the K pieces of 1×(K+M_drop−1) wavelength selecting switches; and

a wavelength selector for selectively outputting signal light having arbitrary wavelength included in output light of the drop signal light multiplexer.

6. The optical transmitting apparatus according to claim 4, wherein the drop wavelength multiplexing and selecting unit comprises:

a drop signal light multiplexer connected to each of the output ports of the K pieces of 1×(K+M_drop−1) wavelength selecting switches and multiplexing outputs of the K pieces of 1×(K+M_drop−1) wavelength selecting switches; and

a wavelength selector for selectively outputting signal light having arbitrary wavelength included in output light of the drop signal light multiplexer.

7. An optical transmitting apparatus comprising:

optical path switching means having a plurality of input ports connected to a plurality of input optical transmission paths for transmitting wavelength division multiplex signal light and a plurality of output ports connected to a plurality of output optical transmission paths for transmitting wavelength division multiplex signal light, capable of selecting signal light of one or more wavelengths included in the wavelength division multiplex signal light received from any of the input ports and outputting the selected wavelength signal light from any of the output ports;

add wavelength output means which combines add signal light having a plurality of wavelengths to obtain a combined signal light and selectively couples add signal light having one or more wavelengths included in the combined signal light, as signal light to be multiplexed to wavelength division multiplex signal light to

any of the output optical transmission paths, to any of the output ports of the optical path switching means; and

drop wavelength output means which selectively receives and combines the signal light having one or more wavelengths included in the wavelength division multiplex signal light input to each of the input ports of the optical path switching means and selectively outputs signal light included in the combined signal light on a wavelength unit basis,

wherein the optical transmitting apparatus is an apparatus to which wavelength division multiplex signal light of the maximum N wavelengths (where N denotes an integer of 2 or larger) is input from each of K pieces of (where K denotes an integer of 2 or larger) input optical transmission paths and which outputs wavelength division multiplex signal light of the maximum N wavelengths to each of the K pieces of output optical transmission paths,

when the minimum integer of integers M satisfying the relation of $M \geqq I_add/N$ where wavelength of add signal light to be output to any of the output optical transmission paths is set as I_add and wavelength of drop signal light to be dropped from any of the input optical transmission paths is set as I_drop is M_add, and the minimum integer of integers M' satisfying the relation of $M \geqq I_drop/N$ is M_drop,

the optical path switching means comprises K pieces of 1×K wavelength selecting switches provided for the K pieces of input optical transmission paths and selectively outputting signal light of one or more arbitrary wavelengths out of the wavelength division multiplex signal light from any of K output ports as the minimum, and K pieces of K-input 1-output multiplexers provided for the K pieces of output optical transmission paths and having K input ports at the minimum and one output port,

to one 1×K wavelength selecting switch, one of the input ports of (K−1) pieces of K-input 1-output multiplexers provided for the (K−1) pieces of output optical transmission paths different from the input optical transmission path for which the 1×K wavelength selecting switch is provided is connected,

the add wavelength output means has M_add pieces of add wavelength multiplexing and selecting units each having K pieces of output ports at the minimum, multiplexing the add signal light of the N wavelengths at the maximum, and selectively outputting add signal light having arbitrary one or more wavelengths from the output ports, and K pieces of M_add-input 1-output multiplexers each having M_add pieces of input ports and one output port, each of the input ports of the M_add-input and 1-output multiplexers is connected to one of the output ports of the M_add pieces of add wavelength multiplexing and selecting units, and the output port of the M_add-input 1-output multiplexer is connected to one of the input ports of the K-input 1-output multiplexer, and

the drop wavelength output means has K pieces of 1×M_drop wavelength selecting switches each of which is connected to one of the output ports of the 1×K wavelength selecting switch and outputting signal light having one or more arbitrary wavelengths out of output light from the 1×K wavelength selecting switch from any of the M_drop pieces of output ports at the minimum; and

M_drop pieces of drop wavelength multiplexing and selecting units each connected to one of output ports of the K pieces of 1×M_drop wavelength selecting switches, multiplexing outputs of the K pieces of 1×M_drop wavelength selecting switches, and selectively outputting drop signal light having arbitrary wavelength.

8. The optical transmitting apparatus according to claim 7, wherein the add wavelength multiplexing and selecting unit comprises:

an add wavelength multiplexer for multiplexing the add signal light; and

a 1×K wavelength selecting switch connected to one of the input ports of each of the K pieces of the M_add-input 1-output multiplexers and selectively outputting signal light having one or more arbitrary wavelengths included in output light of the add wavelength multiplexer to one of the input ports of each of the K pieces of M_add-input 1-output multiplexers.

9. The optical transmitting apparatus according to claim 7, wherein the drop wavelength multiplexing and selecting unit comprises:

a K-input 1-output drop wavelength multiplexer for multiplexing outputs from one of the output ports of each of the K pieces of 1×M_drop wavelength selecting switches; and

a wavelength selector for selectively outputting signal light having arbitrary wavelength included in output light of the drop signal light multiplexer.

10. The optical transmitting apparatus according to claim 8, wherein the drop wavelength multiplexing and selecting unit comprises:

a K-input 1-output drop wavelength multiplexer for multiplexing outputs from one of the output ports of each of the K pieces of 1×M_drop wavelength selecting switches; and

a wavelength selector for selectively outputting signal light having arbitrary wavelength included in output light of the drop signal light multiplexer.

11. A method of adding a path for an optical transmitting apparatus, wherein the number of transmission paths is increased by connecting an optical switch module having wavelength selecting switches of the number required in accordance with the number of transmission paths to be increased to an optical transmitting apparatus having optical path switching means by using an idle port of the wavelength selecting switches in the optical path switching means, and the optical path switching means is connected to a plurality of transmission paths for transmitting wavelength division multiplex signal light and is constructed by a combination of a plurality of wavelength selecting switches to output signal light having any wavelength included in the wavelength division multiplex signal light from a transmission path to another transmission path.

12. The method of adding a path for an optical transmitting apparatus according to claim 11, wherein the wave-

length selecting switch in the optical path switching means is preliminarily provided with an idle port for adding at least one path.

13. The method of adding a path for an optical transmitting apparatus according to claim 12, wherein the number of transmission paths is further increased by preliminarily providing the wavelength selecting switch in the optical switch module with at least one idle port for adding a path so as to prepare for further increase in the number of transmission paths, and connecting another optical switch module by using the idle port.

14. The method of adding a path for an optical transmitting apparatus according to claim 11, wherein the number of transmission paths is further increased by preliminarily providing the wavelength selecting switch in the optical switch module with at least one idle port for adding a path so as to prepare for further increase in the number of transmission paths, and connecting another optical switch module by using the idle port.

15. The method of adding a path for an optical transmitting apparatus according to claim 14, wherein the optical switch module has one or more 1-input k-output (where k denotes an integer of 2 or larger) wavelength selecting switches and one or more k-input 1-output wavelength selecting switch, the input port of said 1-input k-output wavelength selecting switch and the output port of said k-input 1-output wavelength selecting switch are connected to the idle port of the wavelength selecting switch in the optical wavelength selecting means or an add transmission path, and at least one of output ports of said 1-input k-output wavelength selecting switch and at least one of input ports of said k-input 1-output wavelength selecting switch are set as idle ports for connecting said another optical switch module.

16. The method of adding a path for an optical transmitting apparatus according to claim 11, wherein the optical switch module is provided with an optical amplifier for amplifying signal light sent via a plurality of wavelength selecting switches.

17. An optical transmitting apparatus having optical path switching means connected to a plurality of transmission paths for transmitting wavelength division multiplex signal light and constructed by combining a plurality of wavelength selecting switches to output signal light having any wavelength included in the wavelength division multiplex signal light from a transmission path to another transmission path,

wherein the wavelength selecting switch in the optical path switching means is provided with an idle port for connecting an optical switch module constructed by including wavelength selecting switches of the number required in accordance with the number of transmission paths to be added.

18. An optical switch module for adding a path for an optical transmitting apparatus having optical path switching means connected to a plurality of transmission paths for transmitting wavelength division multiplex signal light and constructed by combining a plurality of wavelength selecting switches to output signal light having any wavelength included in the wavelength division multiplex signal light from a transmission path to another transmission path, comprising

wavelength selecting switches of the number necessary in accordance with the number of transmission paths to be added,

wherein the wavelength selecting switches are connected idle ports of the wavelength selecting switches in the optical path switching means in the optical transmitting apparatus.

19. The optical switch module for adding a path to an optical transmitting apparatus according to claim 18, wherein the wavelength selecting switch in the optical switch module is provided with an idle port for adding a path so as to prepare for further increase in the number of transmission paths, and connecting another optical switch module by using the idle port.

20. The optical switch module for adding a path to an optical transmitting apparatus according to claim 19, comprising,

one or more 1-input k-output wavelength selecting switches (where k denotes an integer of 2 or larger) and k-input 1-output wavelength selecting switches as the wavelength selecting switch

in the optical switch module,

wherein the input port of said 1-input k-output wavelength selecting switch and the output port of said k-input 1-output wavelength selecting switch are connected to the idle port of the wavelength selecting switch in the optical wavelength selecting means in the optical transmitting apparatus or an add transmission path, and at least one of the output ports of said 1-input k-output wavelength selecting switch and at least one of the input ports of said k-input 1-output wavelength selecting switch are provided as idle ports for connecting said another optical switch module.

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